APA GROUP

KATHERINE – DARWIN CITY GATE – CHANNEL ISLAND

INVESTIGATION OF INDUCED VOLTAGE MITIGATION REQUIREMENTS

Revision History

Revision	Date	Description
1	10 July 2013	Initial draft for client review
2	26 July 2013	Second draft following preliminary comments
3	7 August 2013	Third draft incorporating client comments and addendum re decommissioning of groundbed at KP 1506
4	23 August 2013	Fourth draft with addenda re Berry Springs MLV and Katherine offtake, and comment re test point alternatives on Channel Island Spur
O	28 August 2013	Final revision, for client distribution

Geoff Cope & Associates Pty Ltd

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APA Group
Investigation of Induced Voltage Mitigation Requirements
Katherine – Darwin City Gate – Channel Island Pipelines

1. Executive Summary

APA Group has a number of cathodic protection installations on the Amadeus Gas Pipeline (AGP) between Katherine and Darwin, on the Channel Island spur pipeline and on the Katherine lateral. High voltage powerlines run in proximity to these pipelines in a number of locations. This study has found that further mitigation of induced voltage effects is warranted at a number of locations:

- the Katherine lateral along its length
- on the AGP as it approaches the Darwin City Gate
- on the Channel Island spurline.

Adequate mitigation for personnel safety can be provided by installation of localised protection at cathodic protection facilities.
Induced voltages due to steady state powerline operation appear presently to be below the levels regarded as likely to cause AC corrosion. However these voltages should continue to be monitored as they may change due to changing powerline loading conditions.

2. Introduction

APA Group is currently progressing with their Cathodic Protection Upgrade Stage 2 project, which involves a combination of new installations and upgrades to existing infrastructure on the AGP. The Channel Island spurline and the Katherine lateral both run in close proximity to paralleling high voltage powerlines, whilst the AGP broadly follows the route of the transmission powerline from Darwin to Katherine. Due to increased powerline loads and new powerline works the situation in relation to the safety of personnel and corrosion of the pipeline needs to be reviewed. APA Group has requested Geoff Cope & Associates carry out a study in accord with AS/NZS 4853 to determine what mitigation is required and consider impacts on the existing CP infrastructure in relation to AS 2832.1.

3. Reference Documents

AS/NZS 4853:2012 Electrical Hazards on Metallic Pipelines

AS 2832.1-2004 Cathodic Protection, Part 1: Pipes and cables

AS 2885.1-2012 Pipelines – Gas and Liquid Petroleum, Part 1: Design and construction

AS 2885.3-2012 – Gas and Liquid Petroleum, Part 3: Operation and Maintenance

Plans, drawings, maps and data as provided by APA Group

Cathodic protection survey data as provided by APA Group

Powerline data and information as provided by PowerWater

Soil resistivity data as obtained by APA Group and Geoff Cope & Associates

4. Pipeline and Powerline Systems

Three pipelines have been studied in this report:

1. The lateral from the AGP supplying gas to Katherine Power Station.
2. The section of the AGP between Katherine and Darwin City Gate.
3. The Channel Island spur pipeline, running from Darwin City Gate to Channel Island.

Each of these is affected by powerlines that run in proximity along parts of their route.

4.1. Lateral pipeline from the AGP to the Katherine Power Station

This pipeline initially runs in an easterly direction from the AGP until meeting Florina Road. For the remainder of its route it runs in general proximity to 22 kV powerlines along Florina Road and Zimin Drive until reaching the Katherine Power Station. Zimin Drive also contains another 22 kV powerline that continue along it south of Florina Road. This line has not been considered in this analysis due to its much shorter length running parallel to the pipeline.

Figure 4.1 Katherine lateral pipeline (light green) and powerline alignment (dark green), with AGP in lower left (bright yellow).

More than half of the pipeline route runs in proximity to the relevant powerline, as shown above. Details of the offset distances can be seen in the software analysis as shown in Appendix 1.

The pipeline had previously been fitted with a number of earthing electrodes, however the present status of these electrodes is uncertain and therefore to take a conservative approach they have not been included in the analysis.

Phase to earth fault current, as provided by PowerWater Corporation, is 13 kA. Indicative data as provided by PowerWater estimated that only 10 - 40% of this current is likely to be returned via the soil path rather than via overhead shield wires, where shield wires are present. Furthermore it is understood that the fault current figure assumes zero resistance earthing, hence the actual fault current to ground at the end of Florina Road is likely to be significantly less. However for the purposes of this analysis it has been assumed the stated fault current would be discharged to ground, corresponding to the worst case conservative scenario.

Soil surface conditions at the time of the field survey were very dry, such that no meaningful data could be obtained using the 4-pin Wenner system. Surface soil samples, taken as appearing typical of the locality, and measured using the 4-electrode soil box method (ref ASTM G57) yielded resistivity values of in excess of 1,100 k ohm cm as taken (dry) and 8.6 k ohm cm when saturated with deionised water. For the LFI analysis a value of 15 k ohm cm has been used.

4.2. AGP between Katherine and Darwin City Gate

Between Katherine and Darwin City Gate the AGP broadly follows the 132 kV supply powerline that runs from Channel Island to Katherine. For much of its route the AGP is at quite considerable distances from the powerline such that induction would be insignificant. However there are also a number of locations where the two are in proximity.

Figure 4.2 AGP (bright yellow) and 132 kV powerline alignment (red), with Stuart Hwy and other major roads in yellow-green.

Pipeline and powerline are in proximity between Helling and Pine Creek (approximately half way to Ban Ban Springs), where the pipeline rejoins the Stuart Highway near Manton as it approaches Darwin, and in the section as the pipeline nears Darwin City Gate.

Other powerlines, which have not been shown, include a 66 kV line from Pine Creek to Cosmo Howley mine, and a 66 kV line from Manton that supplies the area adjacent to the Stuart Highway in the general vicinity towards the Batchelor turnoff.

Site inspection showed that the 66 kV powerline from Manton only runs in moderate proximity (100 to 200 metres separation) for a distance of about 5 km. It is not considered to be of major significance in comparison with the 132 kV supply to Katherine.

Although full route details of the 66 kV line from Pine Creek to Cosmo Howley were not obtained, data that was provided showed only a short section between (approx) KP 1350.5 to KP 1354.5 where the pipeline and powerline are in proximity, at separation distances ranging from 240 to 830 metres. Apart from at this location it would appear that the separation is substantially greater. The phase to earth fault current has been quoted as 920 A at Cosmo Howley. Taken in conjunction with the substantial separation distances for most of the route it is considered that induction from this line should be relatively insignificant.

Information as provided by PowerWater showed phase to earth fault currents on the 132 kV powerline to Katherine as being 2,600 A at Manton zone substation and 1,010 A at Katherine. Fault clearing times are taken as 150 - 200 ms in both instances.

Soil surface conditions between Ban Ban Springs and Katherine at the time of the field survey were very dry and no meaningful data could be obtained using the 4-pin Wenner surface survey system. Soil samples, taken from a location typical of the area between Pine Creek and Helling, measured in excess of 1,100 k ohm cm as found (dry) and 24 k ohm cm (saturated with deionised water) using the 4-electrode soil box method. For the LFI analysis a value of 50 k ohm cm has been used.

An opportunity was provided by road watering equipment to obtain 4-pin Wenner data in Townend Road. Readings obtained indicated surface resistivities of the order of 1,000 ohm cm and deeper layer values of around 500 ohm cm. For the purposes of analysis of the AGP section between Manton and Darwin City Gate a conservative figure of 5,000 ohm cm was adopted.

4.3. Channel Island spur pipeline

The Channel Island spur pipeline runs in proximity to 132 kV powerlines supplying to Hudson Creek and to Katherine via Manton zone substation.

Figure 4.3 Channel Island spurline (yellow) and 132 kV powerlines (red).

Also in this area are 22 kV supplies between Channel Island and Weddell, which have not been shown above.

Soil surface conditions at the time of the field survey were generally very dry such that no meaningful data could be obtained using the 4-pin Wenner system. However slightly moist conditions near the groundbed at KP 1506 enabled some readings to be taken with the soil at each pin thoroughly wetted. Consistent values of approximately 1,000 ohm cm were obtained at all pin separation distances. This value was used throughout for the analysis of the Channel Island spurline, although it is appreciated that some sections (in tidal areas) may be in lower resistivities, whilst other section may be in higher resistivity environments. A conservative approach has therefore been taken in the consideration of the results.

Earthing electrodes have been installed at either side of the Channel Island bridge and at KP 1506. Earthing resistance values as measured using the earth clamp technique were as follows:

Location	Earthing Resistance
Channel Island bridge, west side	2.2 ohms
Channel Island bridge, east side	2.8 ohms
KP 1506, west side	8.0 ohms
KP 1506, east side	7.4 ohms

Earthing resistance was also measured at Darwin City Gate. A nominal value of 1.1 ohms was recorded, however a conservative figure of 2 ohms has been used in the analysis.

Phase to earth fault current levels as provided by PowerWater were as follows:

Location	Fault Current
132 kV powerline, Hudson Creek	6.0 kA
132 kV powerline, Manton ZSS	2.6 kA
22 kV Weddell powerlines	5 kA (nominal)

Fault clearing time: 150 – 200 ms.

5. Methodology

In carrying out the calculations and making assessments, cognizance was taken of the requirements of AS/NZS 4853:2012 – Electrical Hazards on Metallic Pipelines.

Note: The 2012 revision of AS/NZS 4853 resulted in a number of significant changes from the earlier (year 2000) Standard. In particular, personnel safety voltage limits are now based on a quantitative risk assessment for each hazard situation rather than being based on fixed voltage limits. Furthermore, under this Standard, various additional mitigation measures may now be applied, where necessary, to reduce the risk to acceptable levels.

Induced voltage and current calculations were carried out using AC Predictive and Mitigation Software as developed under the auspices of the Pipelines Research Council International and distributed by Technical Toolboxes Inc, USA. This software has been widely used for AC mitigation calculations and design in the pipeline industry. Geoff Cope & Associates is a licensed user of this software and has received training in its use from the programs' author.

Analysis of steady state induction has not been performed analytically in this investigation, as steady state voltage levels on the pipelines can be measured directly. Recordings covering nominal 24 hour periods have been provided by APA group, taken at locations assessed and nominated by Geoff Cope & Associates as being likely to be subject to significant AC induction. The mechanisms of steady state AC corrosion are still being investigated and are yet to be fully understood. Based on values recommended in CIGRE TB 290 (2006) "AC Corrosion on Metallic Pipelines due to Interference from AC Powerlines", and CEN/TS 15280 2006 "Evaluation of AC Corrosion Likelihood on Buried Pipelines", limits of 4 V AC for soils of resistivity less than 2,500 ohm cm, and 10 V AC for higher resistivities are recommended.

Note: Since this study was initiated and the field work undertaken, a review of AS 2832.1-2004, including some consideration of AC corrosion, has further progressed and is now approaching Public Comment. APA Group may need to further evaluate AC corrosion mitigation requirements following publication of the revised Standard.

Pipeline and powerline route maps were provided in electronic form as KMZ files for overlay on Google Earth. This information, in conjunction with Google Earth imaging, was used to determine offset distances between pipeline and powerline in areas of close proximity. (Google Earth images provided sufficient resolution in the areas of interest for powerline towers and conductors to be readily visible such that offset distances and tower separations could be measured using the Google Earth ruler feature.) For the purposes of the software analysis offset distances were loaded in parallel stepwise form rather than in angular orientation. This approach provides greater flexibility in altering the modelling to provide greater resolution in some areas if required, and does not materially affect the outcome when the dominant induction is from long lengths of close parallelism.

In each of the PRC analysis print-outs as shown in the Appendices:

- page 1 provides a general overview of the data used in the analysis
- pages 2 and 3 show the voltage and current distribution along the pipeline as determined by the analysis
- pages 4 and 5 show the powerline and pipeline parameters
- the page sub-titled Section Information shows the length of each pipeline segment, its offset distance from the powerline and the soil resistivity
- the page sub-titled Mitigation & Bond Info shows the location and resistance of earthing on the pipeline

6. Results

6.1 Lateral pipeline from the AGP to the Katherine Power Station

Results of the LFI analysis can be seen in Appendix 1. This shows that voltages of approximately 2.8 kV could be induced under worst case conditions. It should be borne in mind that this voltage is somewhat theoretical as it understood to be based on fault current into zero resistance earthing and the actual fault current to ground at the end of Florina Road is likely to be significantly less. Nevertheless for the purposes of safety it must be assumed that voltages of the order of the calculated value could be present.

Recordings of AC voltage on the pipeline can be seen in Appendix 2. Maximum voltages, as occur on the pipeline towards the Katherine power station, are of the order of 2.5 V.

6.2 AGP between Katherine and Darwin City Gate

For the purposes of analysis this section of the AGP was broken into two sub-sections. The first runs between Helling and Ban Ban Springs, with the second covering Ban Ban Springs to Darwin City Gate. Ban Ban Springs is a convenient break point, and is technically suitable as it is remote from areas of powerline proximity and is at a scraper station, where in-line insulation allows electrical separation between pipeline sections.

6.2.1 Helling to Ban Ban Springs

Results of the LFI analysis can be seen in Appendix 3. It can be seen that voltages of up to approximately 250 V may be induced, with voltages in excess of 150 V present for much of the first 60 km of pipeline north of Helling.

Recordings of AC voltage on this section of pipeline can be seen in Appendix 4. Maximum voltages, as occur towards Pine Creek and Helling, are less than 1 V. It is of interest to note that the highest voltage was recorded at KP 1316.7, north of Pine Creek. At this location the 132 kV Katherine powerline has moved some distance away from the pipeline, and it is understood other powerlines emanate from the power station at Pine Creek. This observation is discussed further later in this report.

6.2.2 Ban Ban Springs to Darwin City Gate

Results of the LFI analysis can be seen in Appendix 5. It can be seen that voltages of up to approximately 1,000 V may be induced, with maximum voltage from this analysis shown as occurring where the pipeline approaches the powerline in the vicinity of pipeline KP 1488. It should be borne in mind with induced voltage calculations that relatively small changes in pipeline earthing can significantly affect the voltage distribution along the pipeline. Accordingly the relativity between voltage maxima between KP 1488 and KP 1498.1 (Darwin City Gate) could easily differ from that shown on the graph.

Recordings of AC voltage on this section of pipeline can be seen in Appendix 6. Voltages south of Manton zone substation are generally of the order of 250 mV or less, whilst those in the section of proximity to the 132 kV powerline between KP 1488 and Darwin City Gate rise to around the order of 2 V.

6.3 Darwin City Gate to Channel Island pipeline (Channel Island spur pipeline)

The Channel Island spur pipeline is influenced by two 132 kV powerlines. One of these is the supply to Manton and then to Katherine, whilst the second supplies towards Hudson Creek. Analysis for these powerlines can be seen in Appendices 7 and 8 (supplies to Katherine and Hudson Creek respectively). Maximum voltage of approximately 500 V were calculated as arising from the Katherine supply due to a fault at Manton, and approximately 800 V due to a fault at Hudson Creek.

Recordings of AC voltage on this section of pipeline can be seen in Appendix 9. Voltages of up to approximately 4 V were recorded, with levels generally being above 2 V.

7. Discussion and Recommendations

7.1 Lateral pipeline from the AGP to the Katherine Power Station

Analysis of pipeline voltages due to powerline fault currents indicate that voltages of up to 3,000 V might be experienced under worst case conditions. To assess compliance with AS/NZS 4853 a risk assessment would formally be required, however it is almost certain that such an assessment would find the calculated voltages to be unacceptable for personnel taking CP readings. Therefore it is recommended that all test points on the Katherine lateral be fitted with touch voltage mitigation measures in the form of grading rings or pads. Refer to Appendix 10 for typical schematic outline sketches.

Voltage levels are expected to be considerably reduced at the ABDP tie-in, as it is understood to be hard bonded. It is understood that no earthing has been installed within the offtake station which might act as a grading ring, however substantial electrical safety is provided by a covering of approximately 100 mm of crushed rock laid directly on the soil surface. A number of indicative contact scenarios as provided by APA group have been analysed using ARGON software in accord with AS/NZS 4853, which have yielded a worst case voltage limit of 1009 V, subject to review of the input data. Maximum voltage in the vicinity of the tie-in has been calculated to be approximately 870 V. The analysis thus suggests that no supplementary safety measures should be required at the Katherine offtake. This conclusion relies heavily on the accuracy of the input data, which needs to be confirmed before acceptance. It should also be noted that the safe voltage limit assumes the integrity and effectiveness of the crushed rock layer, which would need to be maintained at its nominal thickness of 100 mm, free of weeds or other debris which could reduce its electrical insulating properties. Details of the analysis, including input data assumptions, can be seen in Addendum 1.

Consideration has also been given to installation of earthing electrodes to reduce the voltage under fault conditions to levels compliance with AS/NZS 4853. A formal risk assessment would be required to determine the compliant voltage, however the typical scenarios in AS/NZS 4853 suggest a maximum voltage of less than about 500 V would be required, assuming a fault clearing time of less than 200 ms. Given the high resistivity of the soil in this area, reduction to 500 V would require extensive earthing and may not be possible to achieve. Therefore localised reduction of touch voltages by grading rings or pads would appear to be the most viable option.

The installation of grading rings or pads at CP test points will have little effect on touch voltage levels along the pipeline except at these facilities. Therefore if work is being undertaken that involves touching the pipeline at other locations other safety measures will need to be considered, subject to a risk assessment. Possible safety measures and precautions are discussed in AS/NZS 4853, including measures such as temporary installation of insulating mats or conductive mats connected to the pipeline.

Data logger recordings indicate a maximum steady-state AC voltage of less than 2.5 V. This is within the CIGRE TB 290 currently recommended limits in relation to AC corrosion, hence no mitigation for steady state induction is required for compliance.

Note: Refer also to note in Section 5 - Methodology in relation to AC corrosion criteria.

7.2 AGP between Katherine and Darwin City Gate

Analysis of pipeline voltages due to powerline fault currents indicate that voltages of up to approximately 250 V might be experienced near Helling scraper station, and of the order of 1,000 V as the pipeline approaches Darwin City Gate.

To assess compliance with AS/NZS 4853 near Helling a risk assessment for testing at CP test points would in principle be required, however given the fast fault clearing times on the 132 KV Katherine powerline it is considered highly likely that no additional safety measures would be needed. (Under typical scenarios, voltages of up to 500 V or more are considered compliant for most typical operations.) Risk assessment may be important, however, for other work on the pipeline that may involve more than short periods of physical contact.

Voltage under fault conditions as the pipeline approaches Darwin City Gate are in excess of compliant levels as assessed for “typical” situations in AS/NZS 4853. A formal risk assessment could be conducted using situations developed by AGA Group as being appropriate for their operations on the pipeline and fault frequency data obtained from PowerWater Corporation. However based on the information currently available it is recommended that all test points between Darwin City Gate and Townend Road should be fitted with touch voltage mitigation measures in the form of grading rings or pads. Typical schematic outline sketches can be seen in Appendix 10.

In addition to the cathodic protection test points, a line valve at Berry Springs, KP 1486.5, is located in an area of substantial voltage rise as the pipeline approaches Darwin City Gate. Maximum voltage in the vicinity of this line valve has been calculated to be almost 1000 V. A number of contact scenarios provided by APA group have been analysed using ARGON software as per AS/NZS 4853, which have yielded a worst case voltage limit of 1180 V. The analysis thus suggests that no supplementary safety measures should be required at Berry Springs MLV. This conclusion relies heavily on the accuracy of the input data, which should be verified before acceptance. Other line valves are located at Bachelor and Acacia, south of Townend road. Voltages under fault conditions at these locations are much lower than at Berry Springs hence it is considered that no additional measures should be required. Details of the analysis, including input data assumptions, can be seen in Addendum 2.

Data logger recordings indicate a maximum steady-state AC voltage of less than 2 V. This is within the CIGRE TB 290 currently recommended limits in relation to AC corrosion, hence no mitigation of steady state induced voltages is required for compliance.

Note: Refer also to note in Section 5 - Methodology in relation to AC corrosion criteria.

7.3 Darwin City Gate to Channel Island pipeline (Channel Island spur pipeline)

Maximum AC voltage under fault conditions on the Channel Island pipeline are of the order of 800 V. This is in excess of compliant levels as assessed for "typical" situations in AS/NZS 4853. A formal risk assessment could be conducted using situations developed by AGA Group as being appropriate for their operations on the pipeline and fault frequency data obtained from PowerWater Corporation. However based on the information currently available it is recommended that all test points on the Channel Island spurline should be fitted with touch voltage mitigation measures in the form of grading rings or pads. Typical schematic outline sketches can be seen in Appendix 10. Note also that risk assessment and safety measures may be required for works on the pipeline that involve more than short periods of infrequent physical contact.

In principle it would also be quite feasible to reduce voltages on the Channel Island pipeline to lower levels by installation of additional earthing. However quite substantial additional earthing would be required to reduce the voltage to about 400 V. (Earthing resistance would need to be reduced by a factor of about 8.) Also the balance of earthing between each end of the pipeline is moderately critical, and may change seasonally such that the balance is not maintained throughout the year. Localised touch voltage mitigation at test points is therefore recommended as being the more practicable solution.

Subsequent to the initial study, APA Group has asked for comment on the possible decommissioning of the groundbed at KP 1506. This is addressed in Addendum 3 at the end of this report.

APA Group has also advised that two of cathodic protection test points are located about 1 metre from the edge of the roadway on the side of an embankment, such that installation of grading rings may prove to be quite difficult. AS/NZS 4853 provides a number of alternative measures that could be considered. These include:

- providing a non-conductive test point box and surrounding it with a thick layer of bitumen, extending at least 1 metre around the box, so as to insulate operators from the ground whilst accessing the test point. Operators would need to be instructed and trained to avoid simultaneous contact with the pipe and reference electrode terminals.
- wearing electrically rated insulating gloves whilst connecting to the pipe terminal when taking measurements.
- wearing electrically rated insulating footwear and ensuring that no other part of the body (e.g. hand or knee) is touching the ground whilst taking measurements.

Alternatively, perhaps the test points could be relocated to positions more suited to installation of grading rings.

Data logger recordings indicate a maximum steady-state AC voltage of up to approximately 4 V, with levels generally being above 2 V. This is within the CIGRE TB 290 currently recommended limits in relation to AC corrosion, although approaching the borderline for low resistivity soils. Accordingly no mitigation of steady state induced voltages is presently required for compliance. Nevertheless the pipeline is subject to quite significant levels of steady state AC, hence ongoing surveillance is recommended. It is understood that the pipeline is fitted with electrical resistance probes (ERPs) at most or all test points, and that no corrosion has yet been detected. Also it is understood that the pipeline has been subject to coating defect survey, and that a number of coating defects have been identified, examined and repaired with no corrosion being observed. These observations provide substantial confidence that AC corrosion is presently not an issue on this pipeline, hence reduction of steady state AC voltages would appear not to be required. <u>However:</u>

a) It should be confirmed that powerline loads have not increased significantly in recent years, such that the pipeline is now subject to significantly higher voltages which may not yet have been reflected in higher corrosion of the ERPs.
b) Recording of AC voltage levels should be carried out on a regular basis (say every 2 months) such that any seasonal changes in voltage level can be noted and any increasing pattern can be acted upon if necessary.
c) Internal inspection of the pipeline should be strongly considered as a means of providing additional surety that corrosion of any form is under control.

Note: Refer also to note in Section 5 - Methodology in relation to AC corrosion criteria.

7.4 Impact of proposed AC mitigation measures on pipeline cathodic protection

The proposed mitigation measures using grading rings or equipotential pads will have no significant effect on pipeline cathodic protection. As these installations will be decoupled from the pipeline by devices that block flow of current at CP voltage levels they will prevent loss of CP current onto the associated earthing. However some of the decoupling devices exhibit considerable capacitance. They may therefore prevent rapid change in potential such as may be required for correct operation of DCVG coating survey equipment or for obtaining rapid switching "off" potentials on the pipeline. The degree to which the decoupling devices exhibit these effects should be evaluated and considered as part of the selection process. Also in the selection process the current carrying capability of the devices needs to be considered. For example, on the Channel Island pipeline, reference to the fault current graph (Appendix 8 page 3) indicates that nearly 500 A will flow through the devices to earth at each end of the pipeline. I.e. they will need to dissipate 500 A for the duration of the powerline fault.

Geoff Cope
28 August 2013

Appendix 1

Results of LFI analysis for the lateral from the AGP to Katherine Power Station

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Faulted Tower Data

Comments

Comments

LFI analysis - Katherine lateral off AGP
Pipe diameter 115 mm OD
Pipeline coating extruded PE, 1.1 mm thick.
Coating resistance 100 K ohm sq metre (conservatively high value).
Soil resistivity 15,000 ohm cm (from samples tested in soil box box).
Chainage 00 at AGP offtake.
Effective earthing resistance at AGP (due to earthing effect of ABDP) = 0.5 ohm (estimated).
Effective earthing resistance at Katherine power station (due to earthing effect at power station via PCR across MIJ at end of pipeline) = 2 ohms (estimated).
Powerline voltage 22 kV; phase to earth fault current 13,000 A at end pipeline exposure.
section from powerline running from Katherine power station along Zimin Drive and Florina Road.

File Kath22-1.acd

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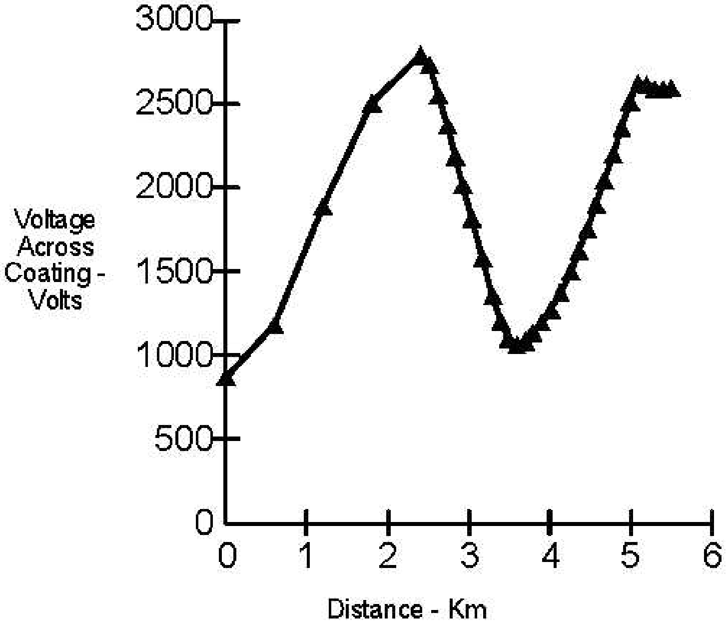
Fault Voltage
Graph and Data



Pipe #1		Pipe #1 (cont.)	
Distance	**Volts**	**Distance**	**Volts**
0.00	868.9	4.88	2354.9
0.60	1184.0	4.98	2516.0
1.20	1890.1	5.09	2622.3
1.80	2505.8	5.19	2615.0
2.40	2789.5	5.29	2585.4
2.51	2729.6	5.39	2589.1
2.62	2548.2	5.49	2591.6
2.73	2368.2		
2.83	2188.1		
2.93	2011.0		
3.03	1813.7		
3.16	1576.9		
3.29	1357.5		
3.39	1202.2		
3.49	1099.0		
3.59	1061.1		
3.69	1086.5		
3.79	1137.5		
3.89	1196.5		
4.01	1272.8		
4.13	1375.1		
4.25	1494.3		
4.35	1620.8		
4.46	1754.1		
4.56	1895.7		
4.67	2043.9		
4.77	2197.3		

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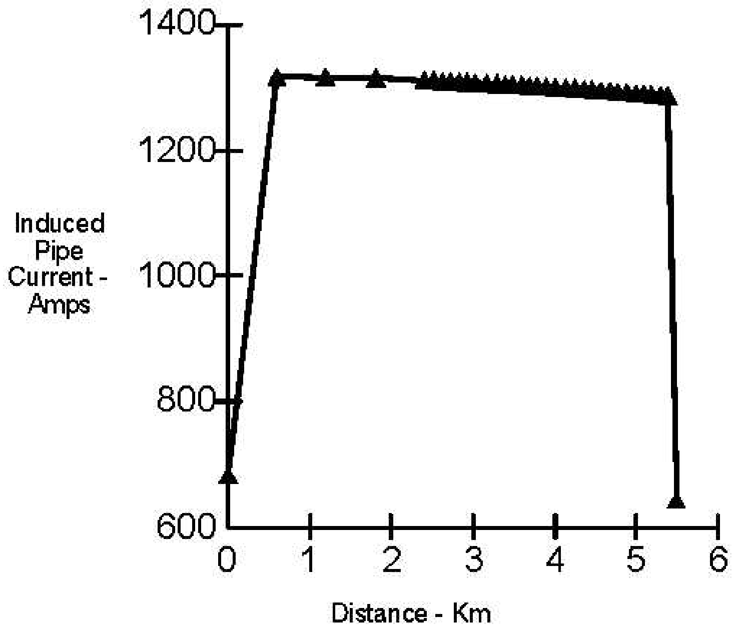
Fault Current
Graph and Data



Pipe #1		Pipe #1 (cont.)	
Distance	Current	Distance	Current
0.00	683.3	4.88	1291.6
0.60	1316.6	4.98	1290.5
1.20	1316.1	5.09	1289.4
1.80	1314.3	5.19	1288.3
2.40	1310.9	5.29	1287.2
2.51	1310.2	5.39	1286.0
2.62	1309.5	5.49	643.8
2.73	1308.8		
2.83	1308.2		
2.93	1307.5		
3.03	1306.9		
3.16	1306.0		
3.29	1305.1		
3.39	1304.4		
3.49	1303.7		
3.59	1303.0		
3.69	1302.2		
3.79	1301.5		
3.89	1300.7		
4.01	1299.7		
4.13	1298.7		
4.25	1297.6		
4.35	1296.7		
4.46	1295.7		
4.56	1294.7		
4.67	1293.7		
4.77	1292.6		

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PRC INTERNATIONAL

Faulted Tower Data
T-Line Information

T-Line

	D - m	H - m	R - ohms/Km	GMR - m
Shield Wire #1	-2.44	10000	10000	0.0008
Shield Wire #2	2.44	10000	10000	0.0008

	D - m	H - m	IL - A	IR - A	Total Current
Phase Wire	0	12	0	13000	13000

	Avg Twr Sep. - m	Avg Twr Res - ohms	Faulted Twr Location
Elec. Sys Parameters	130	10	1

Arc Distance (m) 3.5

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Faulted Tower Data
Pipe Information

Pipe #1

Diameter - m	Burial Depth - m	R - Kohm-m2	Thickness - m
0.115	-1.5	100	0.001

First section **is not** terminated in insulator
Last section **is** terminated in insulator

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Faulted Tower Data
Section Information

Section	Length	Soil Res	L1 - D	L1 - A	L2 - D	L2 - A	L3 - D	L3 - A	L4 - D	L4 - A	L5 - D	L5 - A	P1 - D	P1 - A	P2 - D	P2 - A	P3 - D	P3 - A
1	600	15000	1000	-90									0	0				
2	600	15000	1000	-90									0	0				
3	600	15000	1000	-90									0	0				
4	600	15000	500	0									0	0				
5	110	15000	30	0									0	0				
6	110	15000	30	0									0	0				
7	110	15000	30	0									0	0				
8	100	15000	20	0									0	0				
9	100	15000	20	0									0	0				
10	100	15000	20	0									0	0				
11	130	15000	1	0									0	0				
12	130	15000	1	0									0	0				
13	100	15000	7	0									0	0				
14	100	15000	7	0									0	0				
15	100	15000	7	0									0	0				
16	100	15000	100	0									0	0				
17	100	15000	100	0									0	0				
18	100	15000	100	0									0	0				
19	120	15000	40	0									0	0				
20	120	15000	40	0									0	0				
21	120	15000	40	0									0	0				
22	105	15000	37	0									0	0				
23	105	15000	37	0									0	0				
24	105	15000	37	0									0	0				
25	105	15000	37	0									0	0				
26	105	15000	37	0									0	0				
27	105	15000	37	0									0	0				
28	105	15000	37	0									0	0				
29	105	15000	37	0									0	0				
30	100	15000	250	89.5									0	0				
31	100	15000	250	89.5									0	0				
32	100	15000	250	0									0	0				
33	100	15000	500	89.5									0	0				

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PRC INTERNATIONAL

Faulted Tower Data
Mitigation & Bond Info

Sec/Node	P1-NodeR	P1-AnodeDR	P1-ParWire	P2&1-Bond	P2-NodeR	P2-AnodeDR	P2-ParWire	P3&2-Bond	P3-NodeR	P3-AnodeDR	P3-ParWire	P1&3-Bond
1	0.5											
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												
16												
17												
18												
19												
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21												
22												
23												
24												
25												
26												
27												
28												
29												
30												
31												
32												
33												
34	2											

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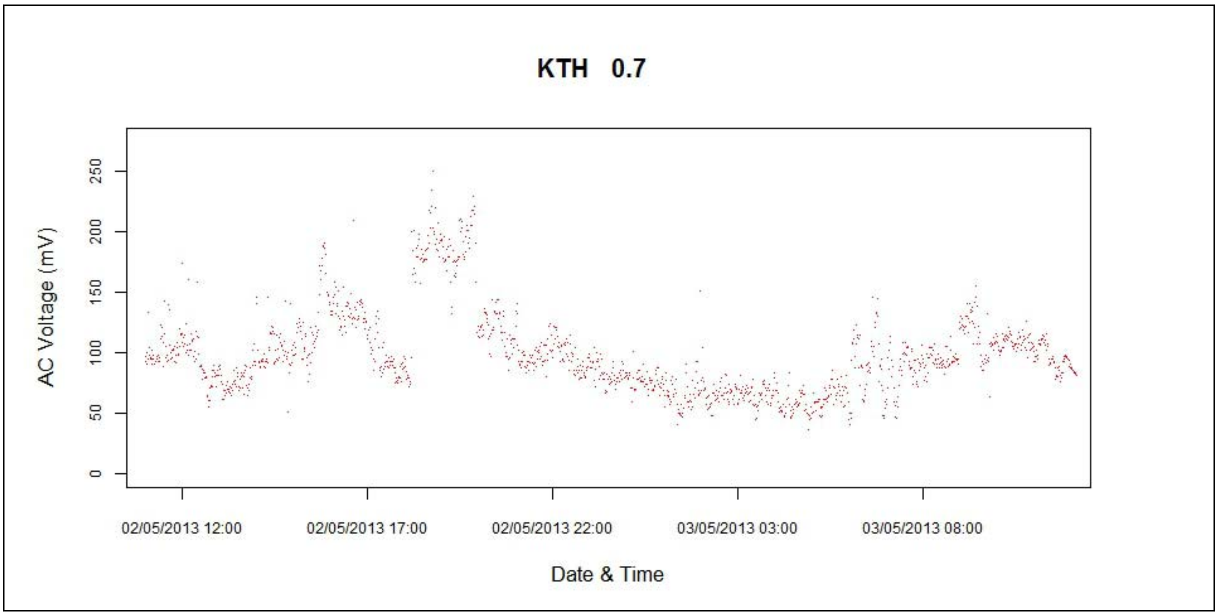
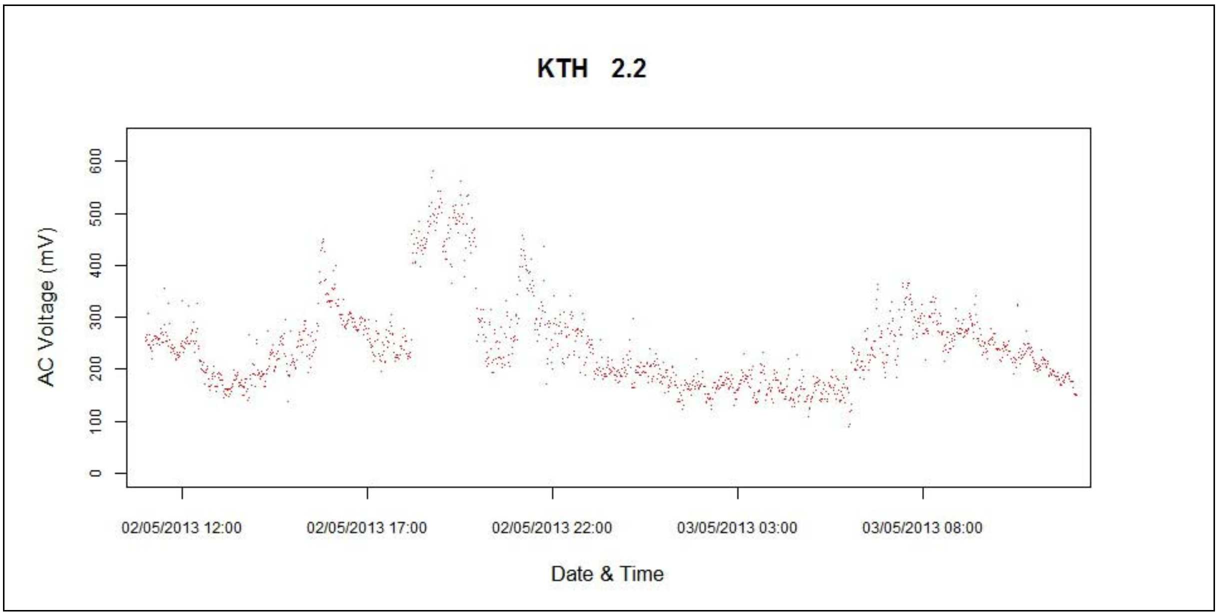
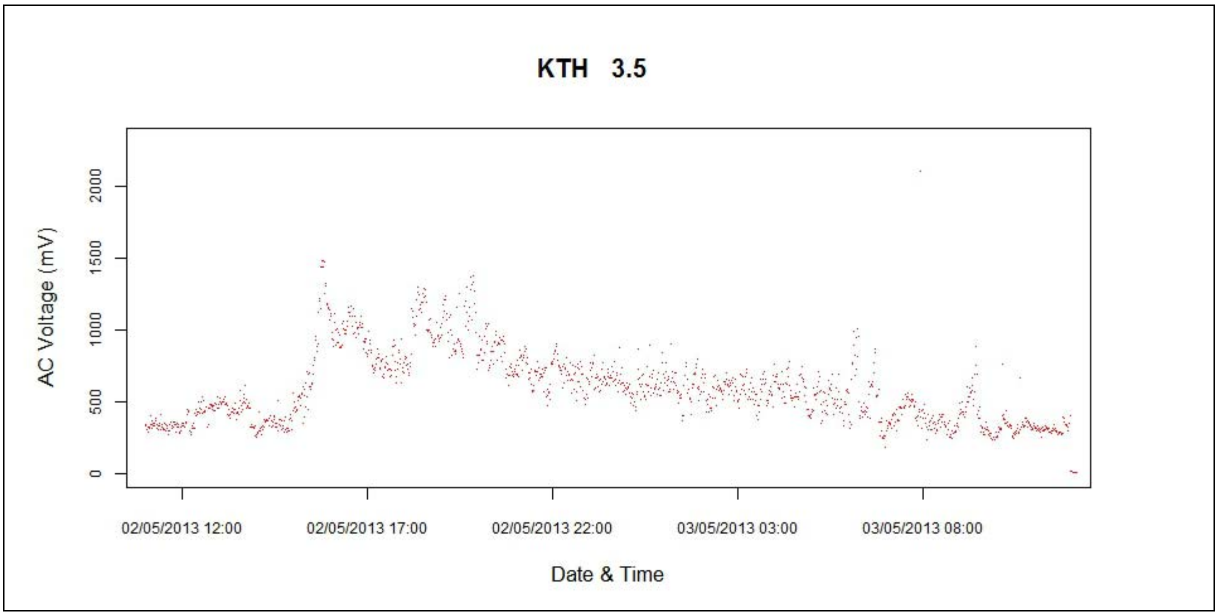
Appendix 2

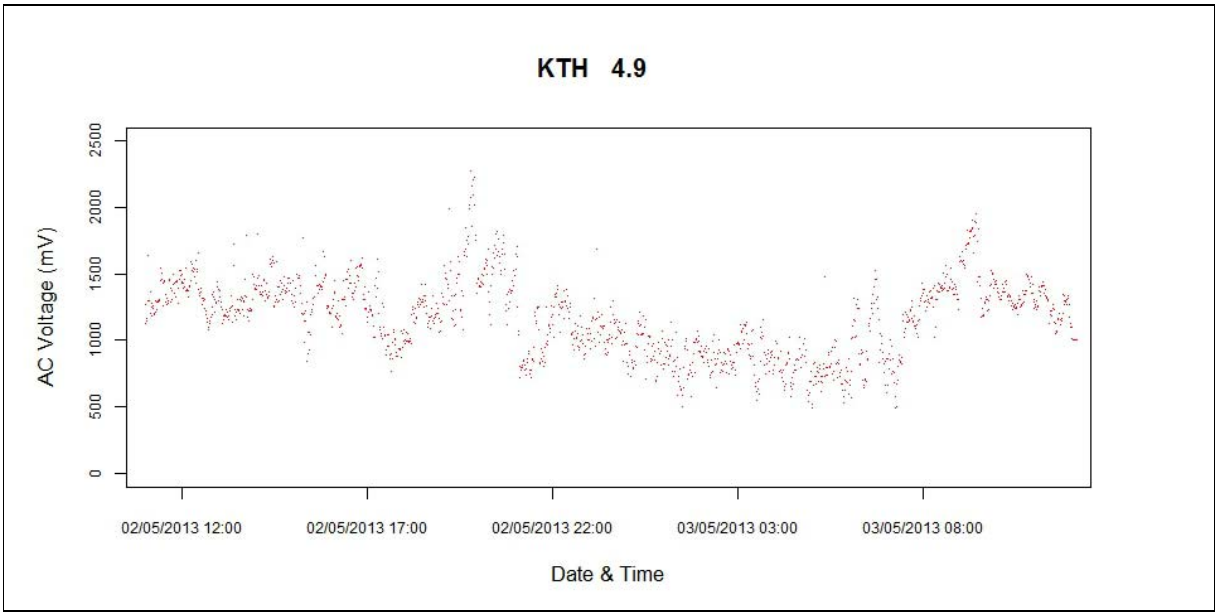
Katherine Lateral Pipeline
AC Recording Data Logger Charts

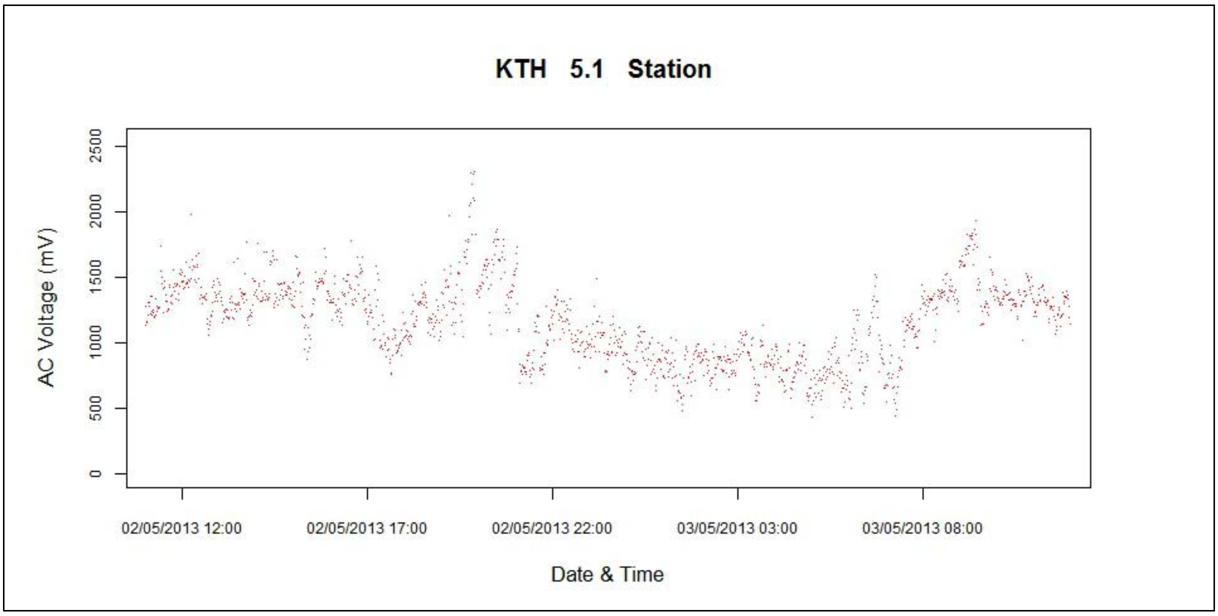
Data logger recordings taken along the pipeline commencing from near the AGP follow below. Recordings were taken at KP 0.7, KP 2.2, KP 3.5, KP 4.9 and KP 5.1 as indicated on each chart respectively.






KTH 3.5
AC Voltage (mV)
0
500
1000
1500
2000
02/05/2013 12:00
02/05/2013 17:00
02/05/2013 22:00
03/05/2013 03:00
03/05/2013 08:00
Date & Time


KTH 4.9
AC Voltage (mV)
0
500
1000
1500
2000
2500
02/05/2013 12:00
02/05/2013 17:00
02/05/2013 22:00
03/05/2013 03:00
03/05/2013 08:00
Date & Time


KTH 5.1 Station
AC Voltage (mV)
0
500
1000
1500
2000
2500
02/05/2013 12:00
02/05/2013 17:00
02/05/2013 22:00
03/05/2013 03:00
03/05/2013 08:00
Date & Time

Appendix 3

Results of LFI analysis for AGP Helling to Ban Ban Springs section

PRC INTERNATIONAL

Faulted Tower Data
Comments

Comments

LFI analysis - AGP Helling to Ban Ban Springs

Pipe diameter 324 mm OD
Pipeline coating extruded PE, thickness 1.1 mm
Coating resistance 100 k ohm sq metre, as calculated from CP data from previous study.
Soil resistivity 50,000 ohm cm (from samples tested in soil box).
Chainage 00 at Helling scraper station.
Powerline voltage 132 kV, phase to earth fault current due to fault at Katherine = 1010 amps.
Nominal earthing 5 ohms assumed at Helling and Ban Ban Springs scraper stations.

File H-BBS-01.acd

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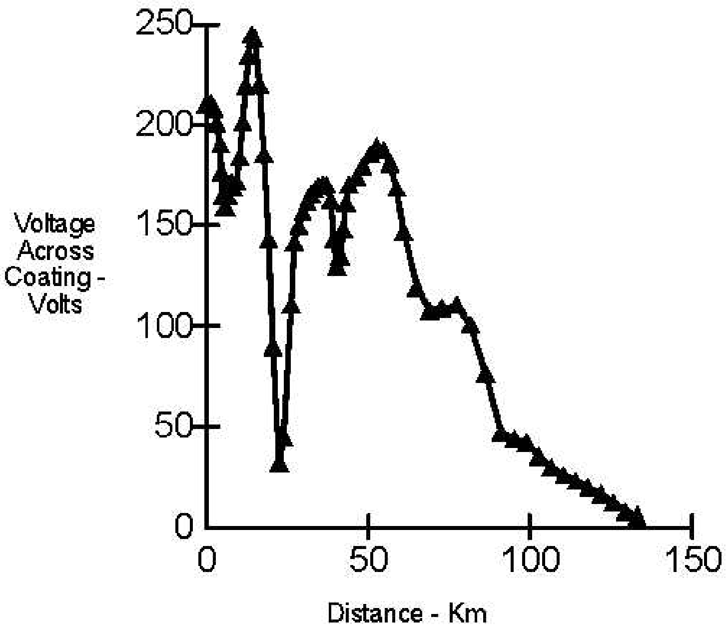
PRC INTERNATIONAL

Fault Voltage
Graph and Data



Pipe #1 Distance	Volts	Pipe #1 (cont.) Distance	Volts	Pipe #1 (cont.) Distance	Volts
0.00	210.3	27.31	141.5	77.14	110.3
1.10	210.9	28.54	149.9	81.66	100.5
2.20	208.4	29.77	156.7	86.18	76.4
3.30	200.4	31.00	161.9	90.70	47.1
4.40	190.2	32.23	165.6	95.22	44.0
4.80	176.5	33.46	168.1	98.98	42.2
5.20	164.9	34.69	169.4	102.74	35.2
5.60	159.0	35.92	170.1	106.50	29.8
6.00	159.0	37.15	170.4	110.26	26.0
6.40	164.9	38.38	162.8	114.02	22.9
6.80	171.0	39.38	143.4	117.78	19.8
7.70	171.1	40.38	129.7	121.54	16.3
8.60	168.8	41.38	135.0	125.30	12.2
9.50	171.8	42.28	148.2	129.06	7.8
10.40	183.7	43.18	161.1	132.82	5.9
11.30	200.9	44.08	170.1		
12.20	218.9	46.18	173.7		
13.10	234.6	48.28	179.1		
13.95	245.2	50.38	185.1		
14.80	243.0	52.48	188.6		
16.23	220.1	54.58	187.6		
17.66	185.2	56.68	181.1		
19.09	143.1	58.78	168.7		
20.72	89.5	60.88	146.8		
22.35	31.8	64.79	119.1		
23.98	45.0	68.71	107.5		
26.08	110.2	72.62	108.8		

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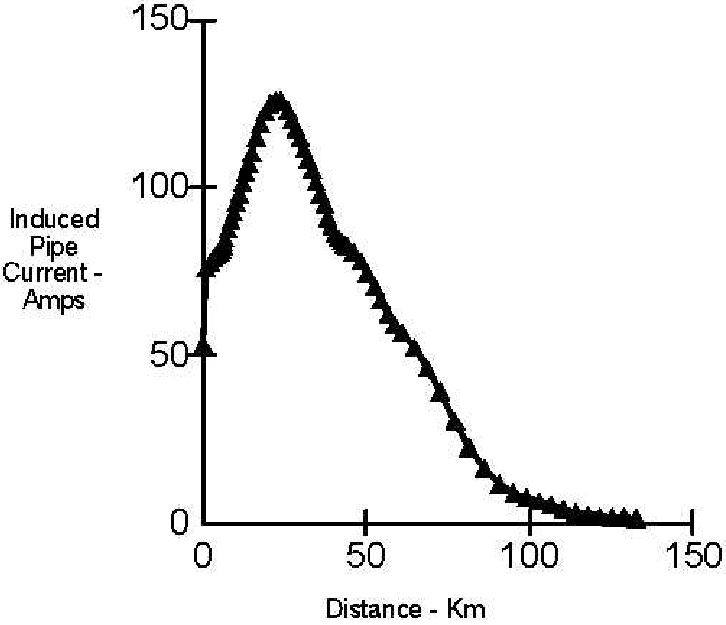
Fault Current
Graph and Data



Pipe #1		Pipe #1 (cont.)		Pipe #1 (cont.)	
Distance	Current	Distance	Current	Distance	Current
0.00	53.3	27.31	120.5	77.14	30.6
1.10	75.8	28.54	117.7	81.66	22.5
2.20	77.5	29.77	114.8	86.18	16.2
3.30	78.9	31.00	111.7	90.70	11.7
4.40	80.0	32.23	108.5	95.22	8.9
4.80	80.5	33.46	105.2	98.98	7.6
5.20	81.0	34.69	101.7	102.74	6.5
5.60	81.8	35.92	98.2	106.50	5.4
6.00	82.6	37.15	94.6	110.26	4.3
6.40	83.6	38.38	91.0	114.02	3.3
6.80	84.8	39.38	88.3	117.78	2.4
7.70	87.5	40.38	86.3	121.54	1.9
8.60	90.1	41.38	84.8	125.30	1.7
9.50	92.7	42.28	83.9	129.06	1.7
10.40	95.4	43.18	83.1	132.82	1.2
11.30	98.1	44.08	82.5		
12.20	101.1	46.18	80.8		
13.10	104.2	48.28	77.9		
13.95	107.2	50.38	74.4		
14.80	110.2	52.48	70.3		
16.23	115.1	54.58	66.2		
17.66	119.1	56.68	62.3		
19.09	122.4	58.78	59.0		
20.72	125.0	60.88	56.6		
22.35	126.2	64.79	52.3		
23.98	125.9	68.71	46.4		
26.08	123.1	72.62	39.3		

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PRC INTERNATIONAL

Faulted Tower Data
T-Line Information

T-Line

	D - m	H - m	R - ohms/Km	GMR - m
Shield Wire #1	-5	25	2.24	0.0008
Shield Wire #2	5	25	2.24	0.0008

	D - m	H - m	IL - A	IR - A	Total Current
Phase Wire	5	21	0	1010	1010

	Avg Twr Sep. - m	Avg Twr Res - ohms	Faulted Twr Location
Elec. Sys Parameters	350	5	1

Arc Distance (m) 1.5

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PRC INTERNATIONAL

Faulted Tower Data
Pipe Information

Pipe #1

Diameter - m	Burial Depth - m	R - Kohm-m2	Thickness - m
0.324	-1.5	100	0.001

First section **is not** terminated in insulator
Last section **is not** terminated in insulator

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PRC INTERNATIONAL

Faulted Tower Data

Section Information

Section	Length	Soil Res	L1 - D	L1 - A	L2 - D	L2 - A	L3 - D	L3 - A	L4 - D	L4 - A	L5 - D	L5 - A	P1 - D	P1 - A	P2 - D	P2 - A	P3 - D	P3 - A
1	1100	50000	1400	0									0	0				
2	1100	50000	1400	0									0	0				
3	1100	50000	1400	0									0	0				
4	1100	50000	1400	0									0	0				
5	400	50000	220	0									0	0				
6	400	50000	220	0									0	0				
7	400	50000	220	0									0	0				
8	400	50000	220	0									0	0				
9	400	50000	220	0									0	0				
10	400	50000	220	0									0	0				
11	900	50000	-650	0									0	0				
12	900	50000	-650	0									0	0				
13	900	50000	-650	0									0	0				
14	900	50000	-480	0									0	0				
15	900	50000	-480	0									0	0				
16	900	50000	-480	0									0	0				
17	900	50000	-480	0									0	0				
18	850	50000	-570	0									0	0				
19	850	50000	-570	0									0	0				
20	1430	50000	-980	0									0	0				
21	1430	50000	-980	0									0	0				
22	1430	50000	-980	0									0	0				
23	1630	50000	-1150	0									0	0				
24	1630	50000	-1150	0									0	0				
25	1630	50000	-1150	0									0	0				
26	2100	50000	-1400	0									0	0				
27	1230	50000	-700	0									0	0				
28	1230	50000	-700	0									0	0				
29	1230	50000	-700	0									0	0				
30	1230	50000	-700	0									0	0				
31	1230	50000	-700	0									0	0				
32	1230	50000	-700	0									0	0				
33	1230	50000	-700	0									0	0				
34	1230	50000	-700	0									0	0				
35	1230	50000	-700	0									0	0				
36	1230	50000	-700	0									0	0				
37	1000	50000	-350	0									0	0				
38	1000	50000	-350	0									0	0				
39	1000	50000	-350	0									0	0				
40	900	50000	-720	0									0	0				
41	900	50000	-720	0									0	0				
42	900	50000	-720	0									0	0				
43	2100	50000	-1500	0									0	0				
44	2100	50000	-1500	0									0	0				
45	2100	50000	-1500	0									0	0				
46	2100	50000	-1500	0									0	0				
47	2100	50000	-1500	0									0	0				
48	2100	50000	-1500	0									0	0				
49	2100	50000	-1500	0									0	0				
50	2100	50000	-1500	0									0	0				
51	3915	50000	-2600	0									0	0				
52	3915	50000	-2600	0									0	0				

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PRC INTERNATIONAL

Steady State Data
Branch Information

Branch	Length	Soil Res	L1 - D	L1 - A	L2 - D	L2 - A	L3 - D	L3 - A	L4 - D	L4 - A	L5 - D	L5 - A	P1 - D	P1 - A	P2 - D	P2 - A	P3 - D	P3 - A
53	3915	50000	-2600	0									0	0				
54	4520	50000	-2600	0									0	0				
55	4520	50000	-2600	0									0	0				
56	4520	50000	-2600	0									0	0				
57	4520	50000	-2600	0									0	0				
58	4520	50000	-2600	0									0	0				
59	3160	50000	-20000	0									0	0				
60	3160	50000	-20000	0									0	0				
61	3160	50000	-20000	0									0	0				
62	3160	50000	-20000	0									0	0				
63	3160	50000	-20000	0									0	0				
64	3160	50000	-20000	0									0	0				
65	3160	50000	-20000	0									0	0				
66	3160	50000	-20000	0									0	0				
67	3160	50000	-20000	0									0	0				
68	3160	50000	-20000	0									0	0				

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PRC INTERNATIONAL

Faulted Tower Data
Mitigation & Bond Info

Sec/Node	P1-NodeR	P1-AnodeDR	P1-ParWire	P2&1-Bond	P2-NodeR	P2-AnodeDR	P2-ParWire	P3&2-Bond	P3-NodeR	P3-AnodeDR	P3-ParWire	P1&3-Bond
1	5											
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
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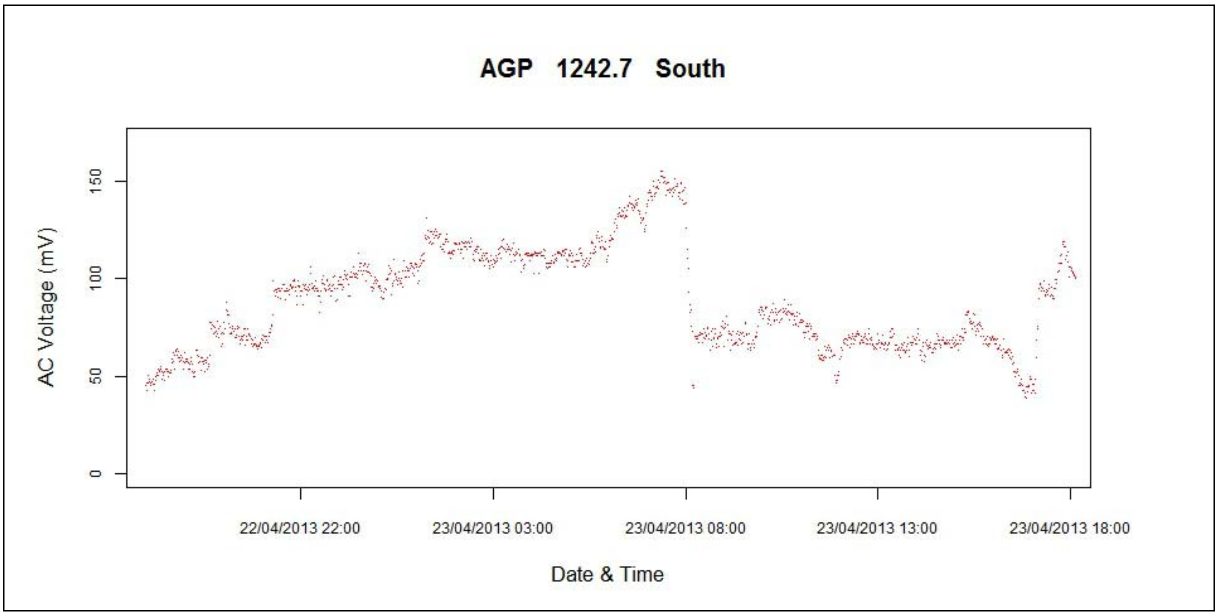
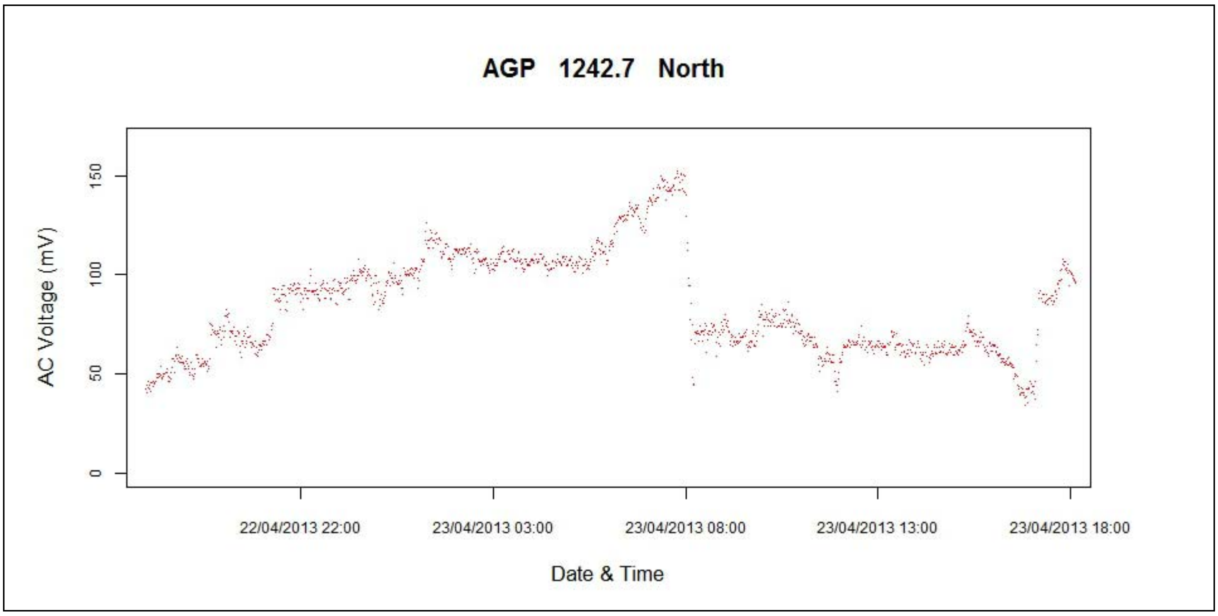
62												
63												
64												
65												
66												
67												
68												
69	5											

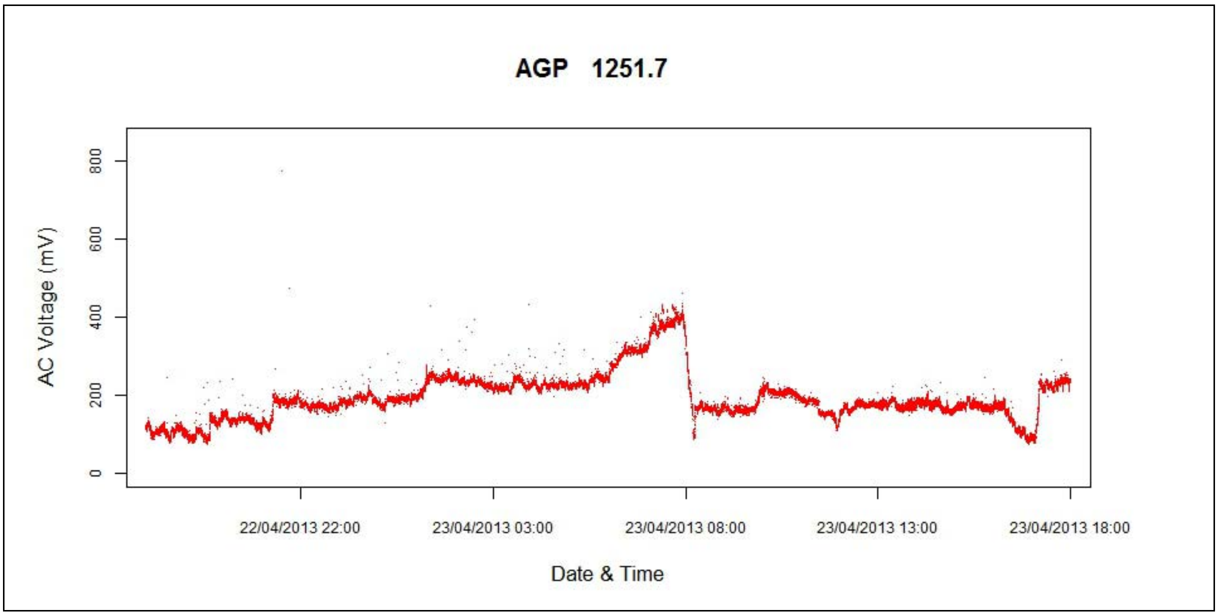
Appendix 4

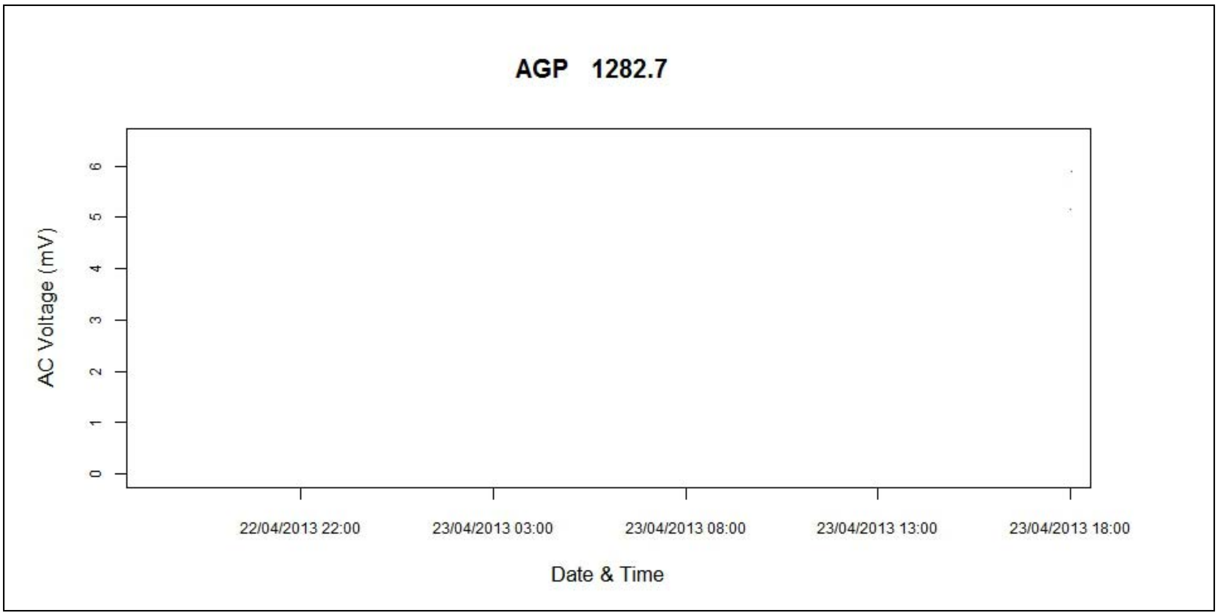
Helling to Ban Ban Springs
AC Recording Data Logger Charts

Data logger recordings taken along the AGP between Helling and Ban Ban Springs follow below. Recordings were taken at KPs 1242.7 south, 1242.7 north, 1251.7, 1282.7, 1296, 1316.7, 1338.9. 1352.8, 1354.2 and 1374.9 as shown on each chart respectively.

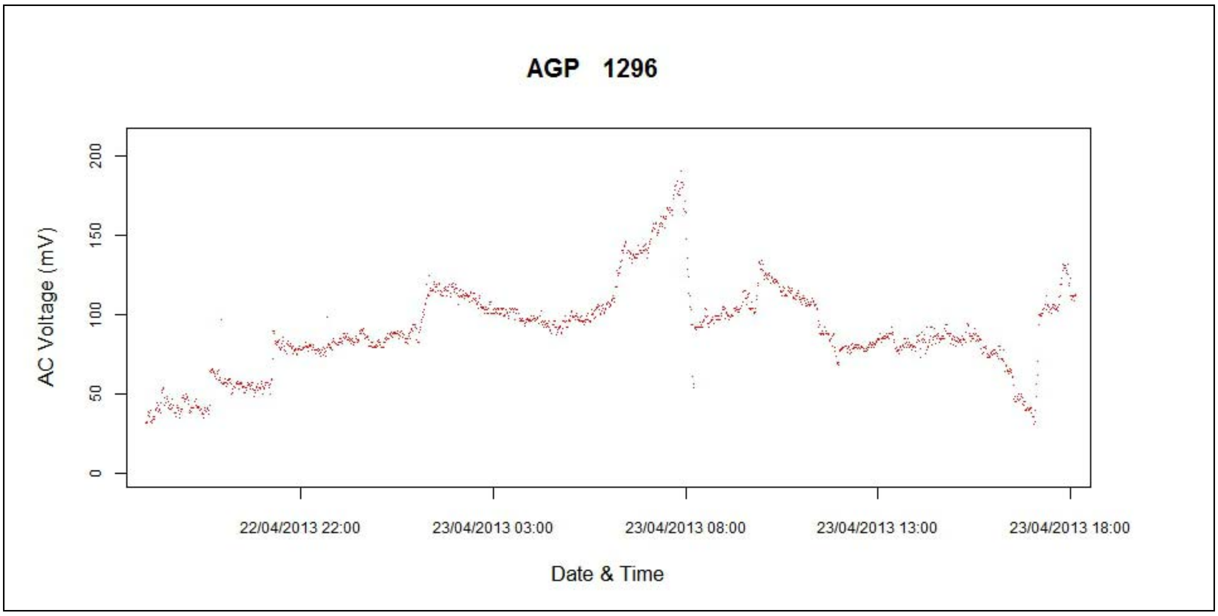


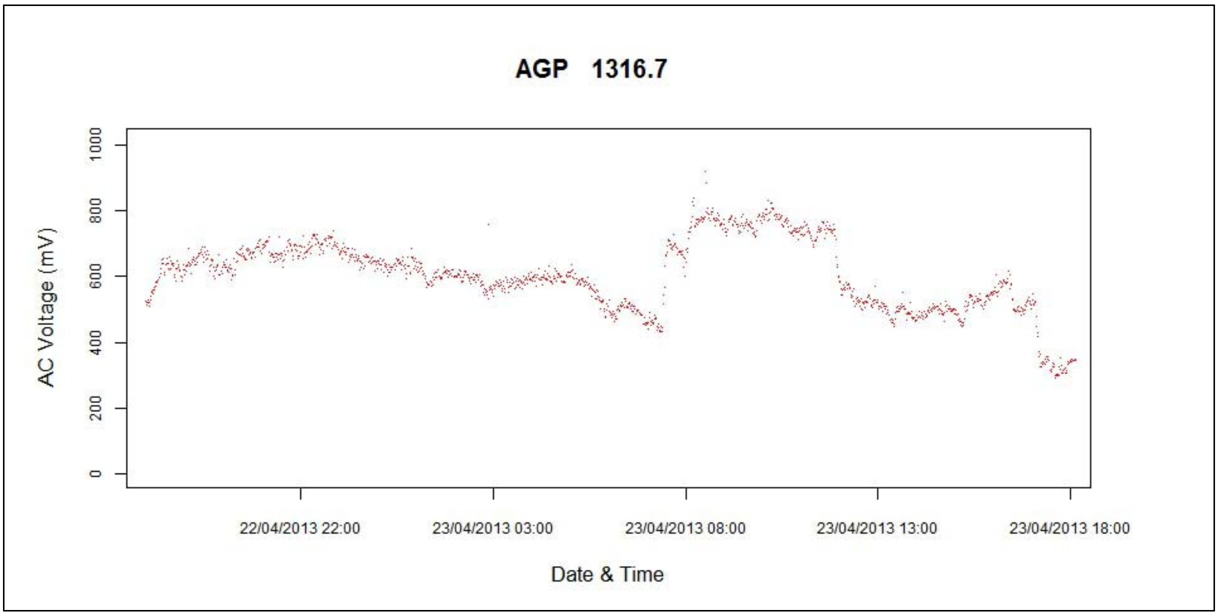


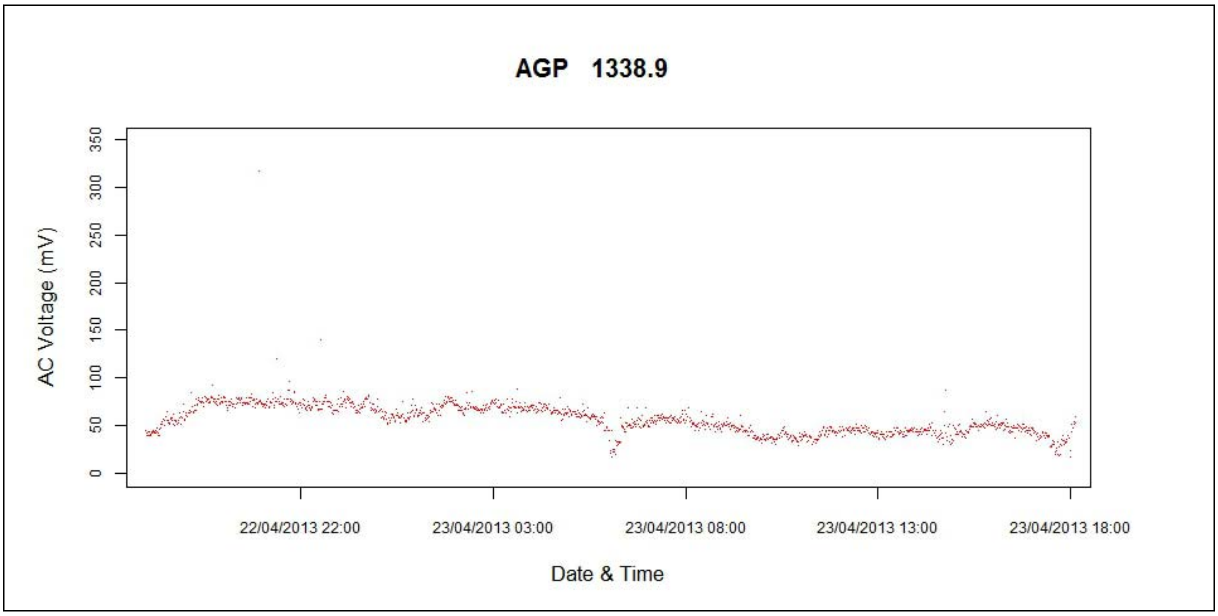


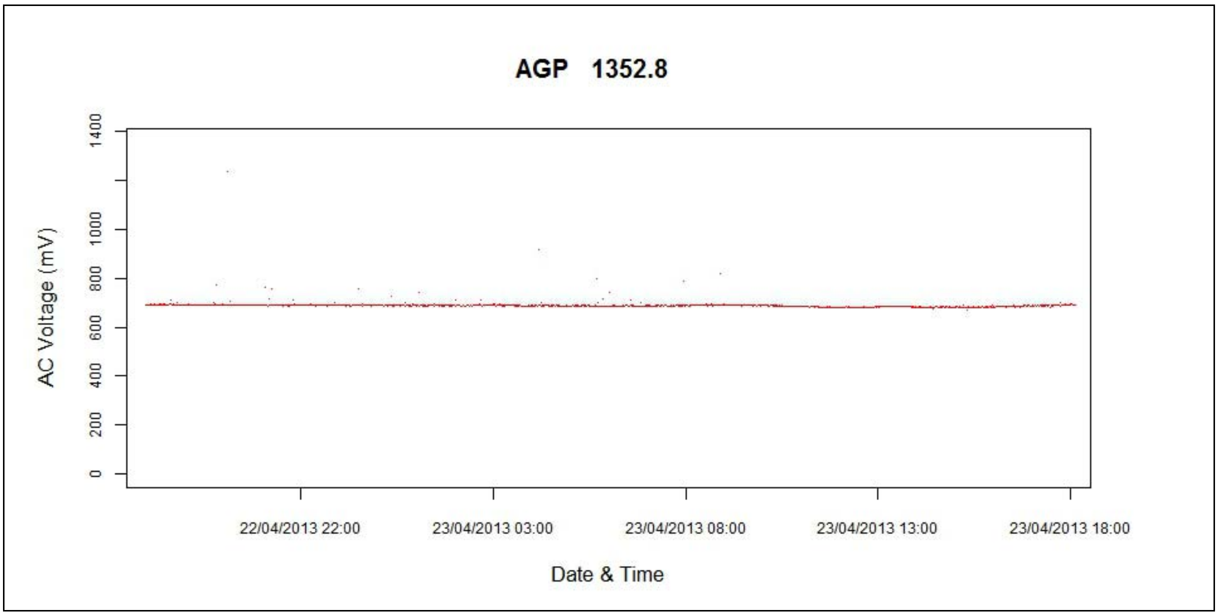


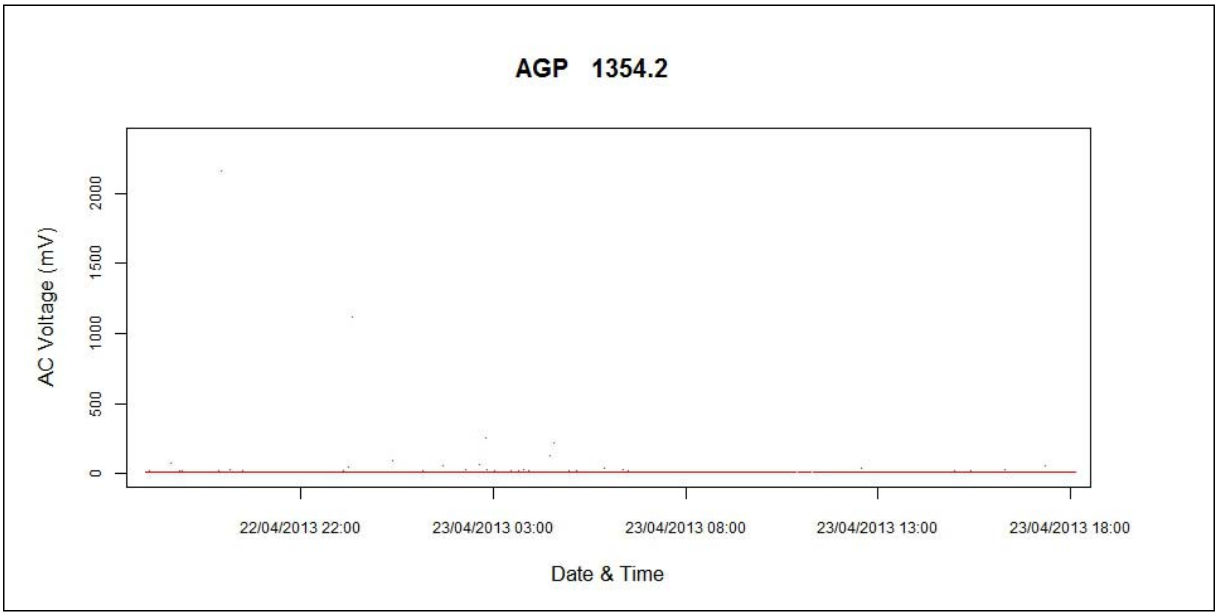
Note: This chart appears to show no data, hence it is likely that an error has occurred in the data logging. As the recordings taken either side of this test point show low levels of AC there would appear to be no need for this recording to be repeated at this time.

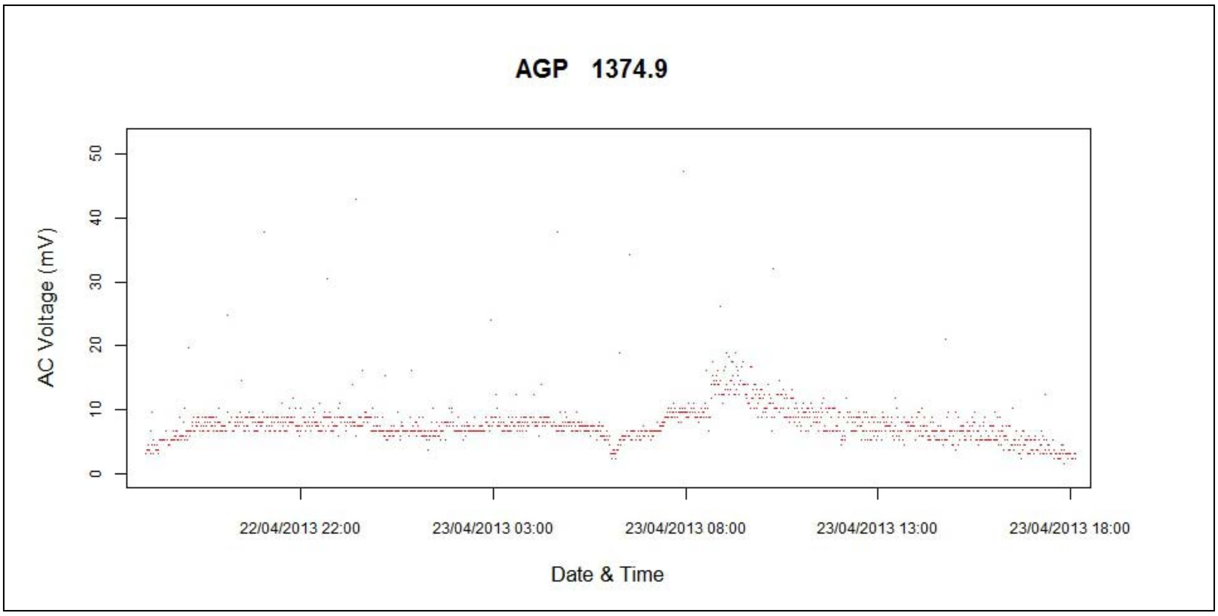

AGP 1296
AC Voltage (mV)
0
50
100
150
200
22/04/2013 22:00
23/04/2013 03:00
23/04/2013 08:00
23/04/2013 13:00
23/04/2013 18:00
Date & Time


AGP 1316.7
AC Voltage (mV)
0
200
400
600
800
1000
22/04/2013 22:00
23/04/2013 03:00
23/04/2013 08:00
23/04/2013 13:00
23/04/2013 18:00
Date & Time


AGP 1338.9
AC Voltage (mV)
0
50
100
150
200
250
300
350
22/04/2013 22:00
23/04/2013 03:00
23/04/2013 08:00
23/04/2013 13:00
23/04/2013 18:00
Date & Time


AGP 1352.8
AC Voltage (mV)
0
200
400
600
800
1000
1400
22/04/2013 22:00
23/04/2013 03:00
23/04/2013 08:00
23/04/2013 13:00
23/04/2013 18:00
Date & Time


AGP 1354.2
AC Voltage (mV)
0
500
1000
1500
2000
22/04/2013 22:00
23/04/2013 03:00
23/04/2013 08:00
23/04/2013 13:00
23/04/2013 18:00
Date & Time


AGP 1374.9
AC Voltage (mV)
0
10
20
30
40
50
22/04/2013 22:00
23/04/2013 03:00
23/04/2013 08:00
23/04/2013 13:00
23/04/2013 18:00
Date & Time

Appendix 5

Results of LFI analysis for AGP Ban Ban Springs to Darwin City Gate section

Between Ban Ban Springs and Manton zone substation the AGP is generally at a substantial distance from the 132 kV powerline to Katherine, such that relatively low levels of induction are to be expected. This expectation was further confirmed by the relatively low levels of steady state AC voltage observed on the data logger recordings for this section (see Appendix 6). The software analysis which follows therefore covers only the section from Darwin City Gate to Manton zone substation.

Note that chainage shown on the graphs commences from Darwin City Gate (0 km)

PRC INTERNATIONAL

Faulted Tower Data
Comments

Comments

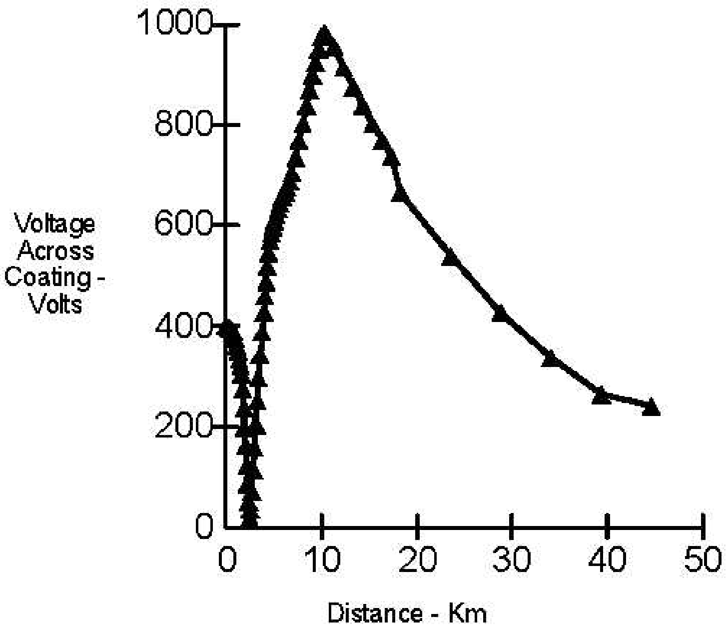
LFI analysis - AGP Darwin City Gate to Manton zone substation

Pipe diameter = 324 mm OD
Pipeline coated with extruded PE, thickness 1.1 mm
Coating resistance 100 k ohm sq metre, as estimated based on CP data from previous study.
Soil resistivity 5,000 ohm cm based on readings at Townend Road and general observation of soil type along the route.
Chainage 00 at Darwin City Gate.
Powerline voltage 132 kV, phase to earth fault current due to fault at Manton zone substation = 2,600 A.
Nominal earth 2 ohms at Darwin City Gate.

File HV-DM-01.acd

PRC INTERNATIONAL

Fault Voltage
Graph and Data



Pipe #1 Distance	Volts	Pipe #1 (cont.) Distance	Volts	Pipe #1 (cont.) Distance	Volts
0.00	400.1	3.93	427.3	11.35	955.1
0.25	397.0	4.07	459.6	12.35	913.6
0.50	392.9	4.20	488.0	13.35	874.2
0.75	387.7	4.34	516.3	14.35	837.0
0.90	376.2	4.47	544.7	15.35	801.6
1.05	361.5	4.61	568.6	16.35	768.0
1.20	347.4	4.78	584.0	17.35	736.1
1.35	334.0	4.96	595.5	18.35	664.9
1.50	321.4	5.13	607.5	23.61	539.4
1.65	303.2	5.31	620.0	28.87	425.7
1.75	272.3	5.48	632.9	34.13	336.2
1.85	234.9	5.66	644.9	39.38	264.6
1.95	197.5	5.91	654.9	44.64	239.6
2.05	160.1	6.16	664.7		
2.15	122.9	6.41	675.4		
2.25	85.9	6.66	686.9		
2.35	49.8	6.91	704.6		
2.45	20.0	7.29	733.5		
2.55	33.8	7.67	768.0		
2.65	70.4	8.05	802.5		
2.80	113.0	8.43	836.9		
2.95	158.5	8.81	869.2		
3.10	204.4	9.11	897.6		
3.25	250.3	9.42	923.8		
3.40	296.3	9.73	949.6		
3.55	341.9	10.04	975.0		
3.74	386.8	10.35	982.2		

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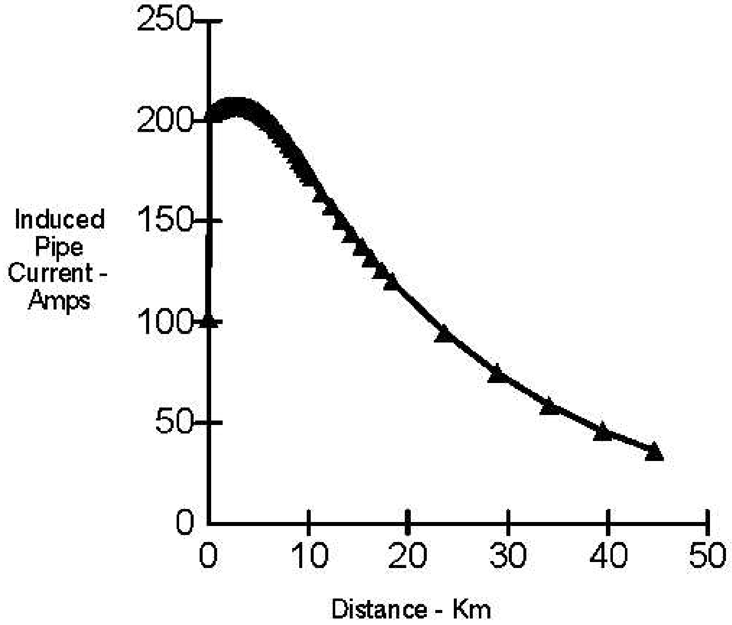
PRC INTERNATIONAL

Fault Current
Graph and Data



Pipe #1 Distance	Current	Pipe #1 (cont.) Distance	Current	Pipe #1 (cont.) Distance	Current
0.00	101.3	3.93	206.5	11.35	164.0
0.25	203.2	4.07	206.3	12.35	157.0
0.50	204.1	4.20	206.1	13.35	150.2
0.75	204.9	4.34	205.8	14.35	143.7
0.90	205.3	4.47	205.6	15.35	137.5
1.05	205.7	4.61	205.3	16.35	131.4
1.20	206.0	4.78	204.8	17.35	125.6
1.35	206.3	4.96	204.4	18.35	120.1
1.50	206.5	5.13	203.9	23.61	94.8
1.65	206.7	5.31	203.3	28.87	74.6
1.75	206.8	5.48	202.7	34.13	58.5
1.85	206.9	5.66	202.0	39.38	45.8
1.95	207.0	5.91	201.0	44.64	36.0
2.05	207.0	6.16	199.9		
2.15	207.1	6.41	198.7		
2.25	207.2	6.66	197.3		
2.35	207.2	6.91	195.9		
2.45	207.3	7.29	193.7		
2.55	207.3	7.67	191.3		
2.65	207.3	8.05	188.7		
2.80	207.3	8.43	186.0		
2.95	207.3	8.81	183.2		
3.10	207.2	9.11	180.9		
3.25	207.2	9.42	178.5		
3.40	207.1	9.73	176.1		
3.55	207.0	10.04	173.8		
3.74	206.8	10.35	171.4		

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PRC INTERNATIONAL

Faulted Tower Data
T-Line Information

T-Line

	D - m	H - m	R - ohms/Km	GMR - m
Shield Wire #1	-5	25	2.24	0.0008
Shield Wire #2	5	25	2.24	0.0008

	D - m	H - m	IL - A	IR - A	Total Current
Phase Wire	-5	21	2600	0	2600

	Avg Twr Sep. - m	Avg Twr Res - ohms	Faulted Twr Location
Elec. Sys Parameters	350	5	67

Arc Distance (m) 0.5

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PRC INTERNATIONAL

Faulted Tower Data
Pipe Information

Pipe #1

Diameter - m	Burial Depth - m	R - Kohm-m2	Thickness - m
0.324	-1.5	100	0.001

First section **is** terminated in insulator
Last section **is not** terminated in insulator

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PRC INTERNATIONAL

Faulted Tower Data

Section Information

Section	Length	Soil Res	L1 - D	L1 - A	L2 - D	L2 - A	L3 - D	L3 - A	L4 - D	L4 - A	L5 - D	L5 - A	P1 - D	P1 - A	P2 - D	P2 - A	P3 - D	P3 - A
1	250	5000	700	0									0	0				
2	250	5000	700	0									0	0				
3	250	5000	700	0									0	0				
4	150	5000	300	0									0	0				
5	150	5000	300	0									0	0				
6	150	5000	300	0									0	0				
7	150	5000	300	0									0	0				
8	150	5000	300	0									0	0				
9	150	5000	300	0									0	0				
10	100	5000	25	0									0	0				
11	100	5000	25	0									0	0				
12	100	5000	25	0									0	0				
13	100	5000	25	0									0	0				
14	100	5000	25	0									0	0				
15	100	5000	25	0									0	0				
16	100	5000	25	0									0	0				
17	100	5000	25	0									0	0				
18	100	5000	25	0									0	0				
19	100	5000	25	0									0	0				
20	150	5000	50	0									0	0				
21	150	5000	50	0									0	0				
22	150	5000	50	0									0	0				
23	150	5000	50	0									0	0				
24	150	5000	50	0									0	0				
25	150	5000	50	0									0	0				
26	190	5000	90	0									0	0				
27	190	5000	90	0									0	0				
28	135	5000	110	0									0	0				
29	135	5000	110	0									0	0				
30	135	5000	110	0									0	0				
31	135	5000	110	0									0	0				
32	135	5000	110	0									0	0				
33	175	5000	350	0									0	0				
34	175	5000	350	0									0	0				
35	175	5000	350	0									0	0				
36	175	5000	350	0									0	0				
37	175	5000	350	0									0	0				
38	175	5000	350	0									0	0				
39	250	5000	500	0									0	0				
40	250	5000	500	0									0	0				
41	250	5000	500	0									0	0				
42	250	5000	500	0									0	0				
43	250	5000	500	0									0	0				
44	380	5000	350	0									0	0				
45	380	5000	350	0									0	0				
46	380	5000	350	0									0	0				
47	380	5000	350	0									0	0				
48	380	5000	350	0									0	0				
49	308	5000	360	0									0	0				
50	308	5000	360	0									0	0				
51	308	5000	360	0									0	0				
52	308	5000	360	0									0	0				
53	308	5000	360	0									0	0				
54	1000	5000	3500	0									0	0				
55	1000	5000	3500	0									0	0				
56	1000	5000	3500	0									0	0				
57	1000	5000	3500	0									0	0				
58	1000	5000	3500	0									0	0				
59	1000	5000	3500	0									0	0				
60	1000	5000	3500	0									0	0				
61	1000	5000	3500	0									0	0				
62	5260	5000	8500	0									0	0				
63	5260	5000	8500	0									0	0				
64	5260	5000	8500	0									0	0				
65	5260	5000	8500	0									0	0				
66	5260	5000	8500	0									0	0				

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Faulted Tower Data
Mitigation & Bond Info

Sec/Node	P1-NodeR	P1-AnodeDR	P1-ParWire	P2&1-Bond	P2-NodeR	P2-AnodeDR	P2-ParWire	P3&2-Bond	P3-NodeR	P3-AnodeDR	P3-ParWire	P1&3-Bond
1	2											
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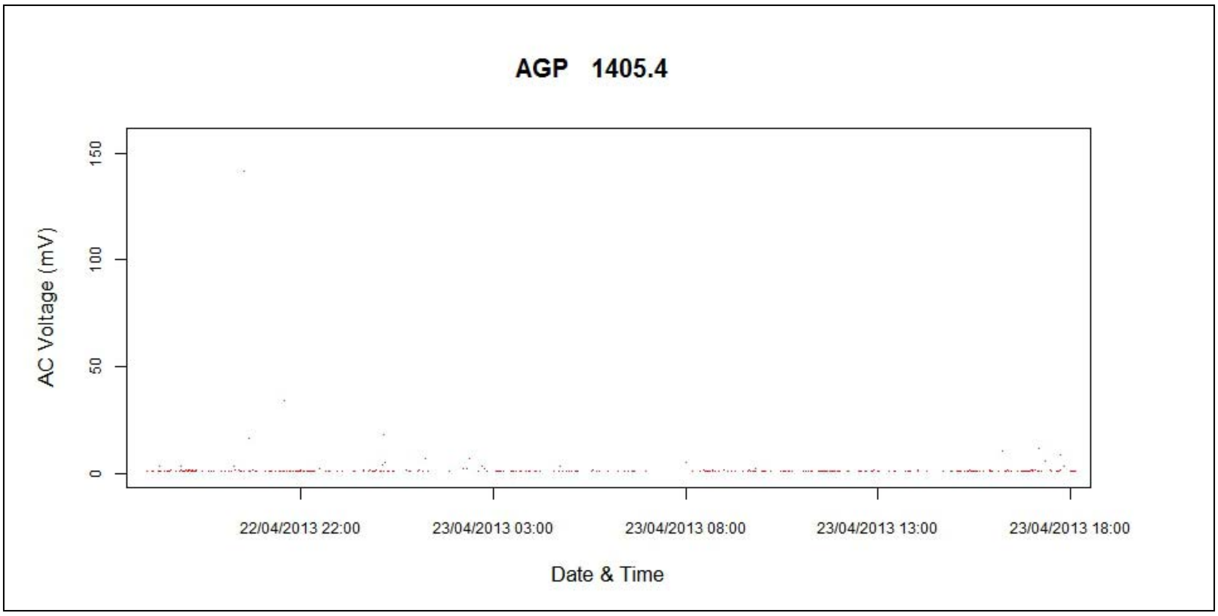
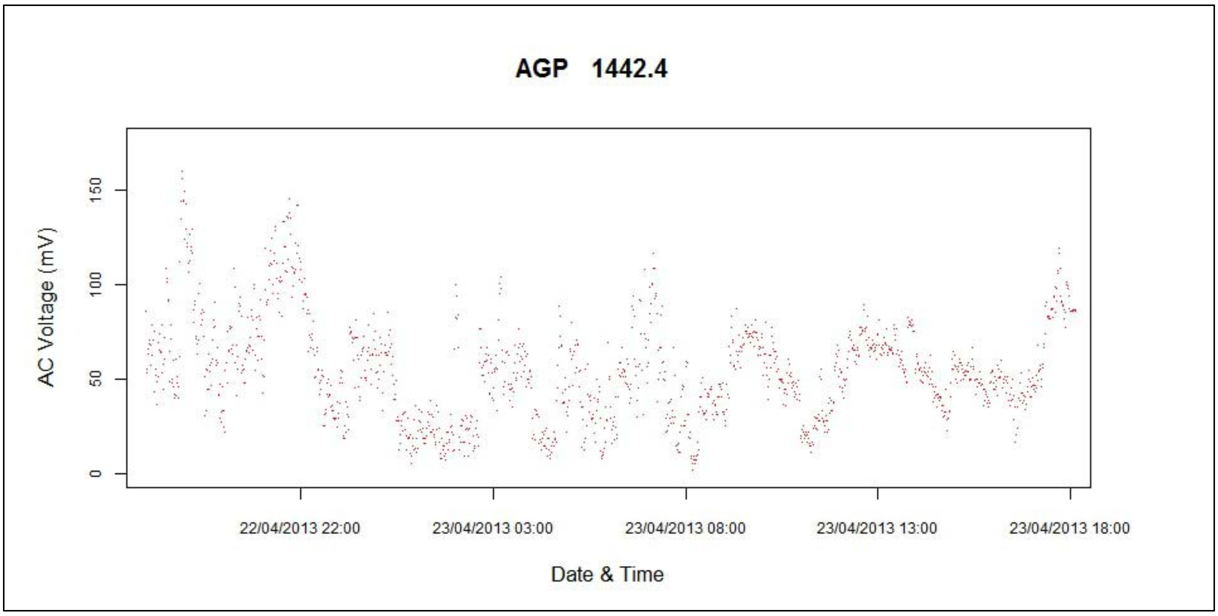
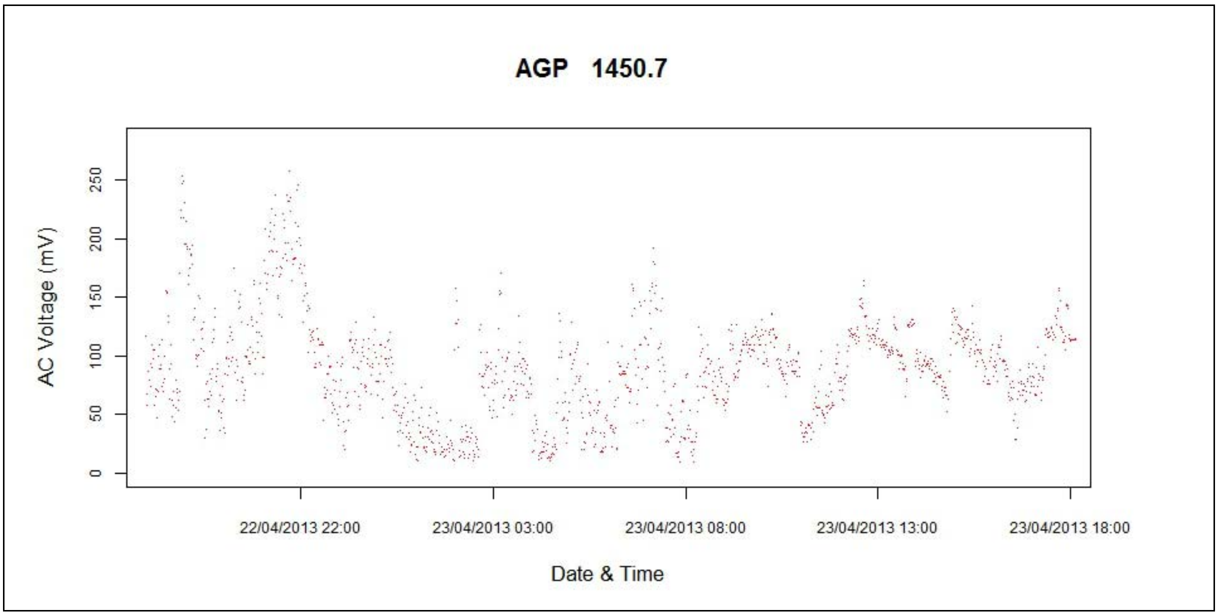
Appendix 6

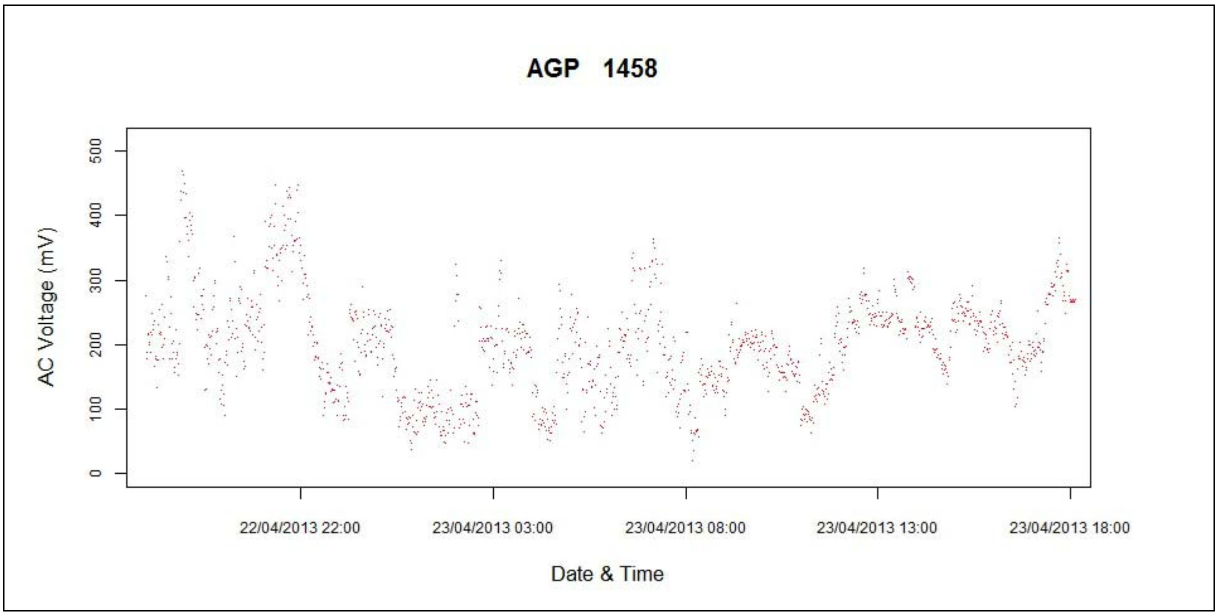
Ban Ban Springs to Darwin City Gate Springs
AC Recording Data Logger Charts

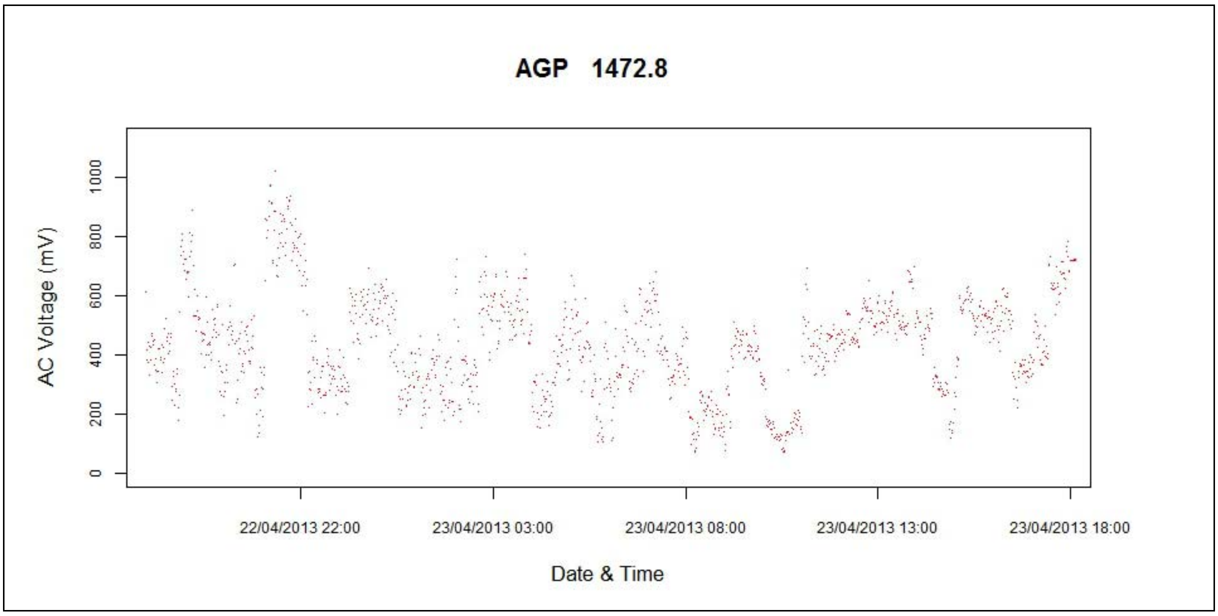
Data logger recordings taken along the AGP between Ban Ban Springs and Darwin City Gate follow below. Recordings were taken at KPs 1405.4, 1442.4, 1450.7, 1458, 1472.8, 1488.8, 1494.4. 1497.2, as shown on each chart respectively.

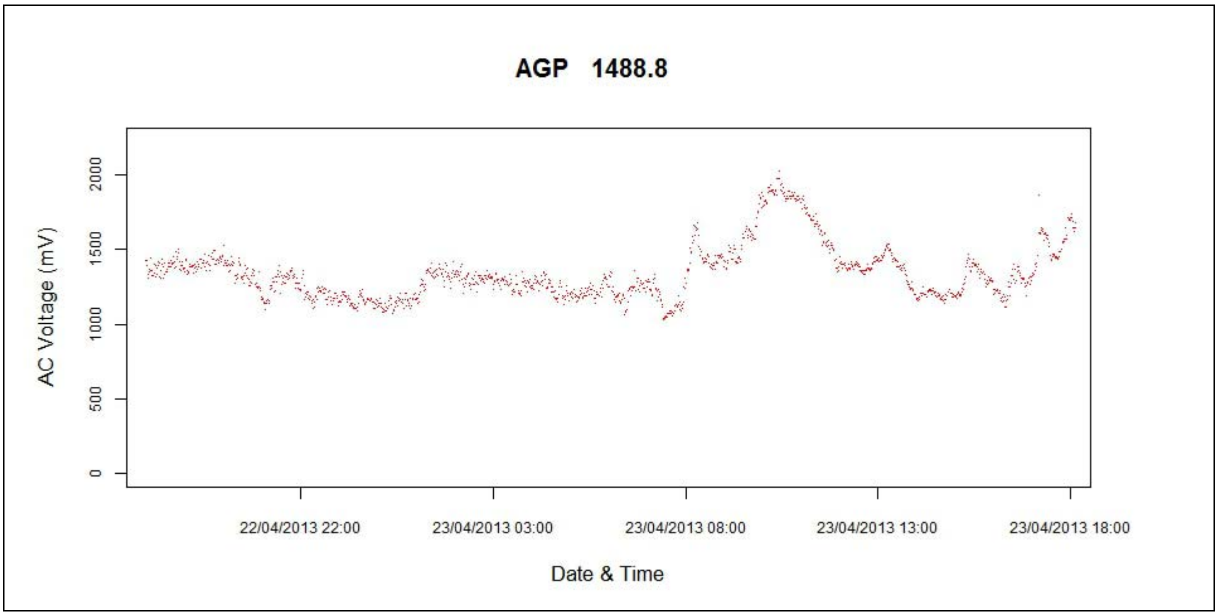


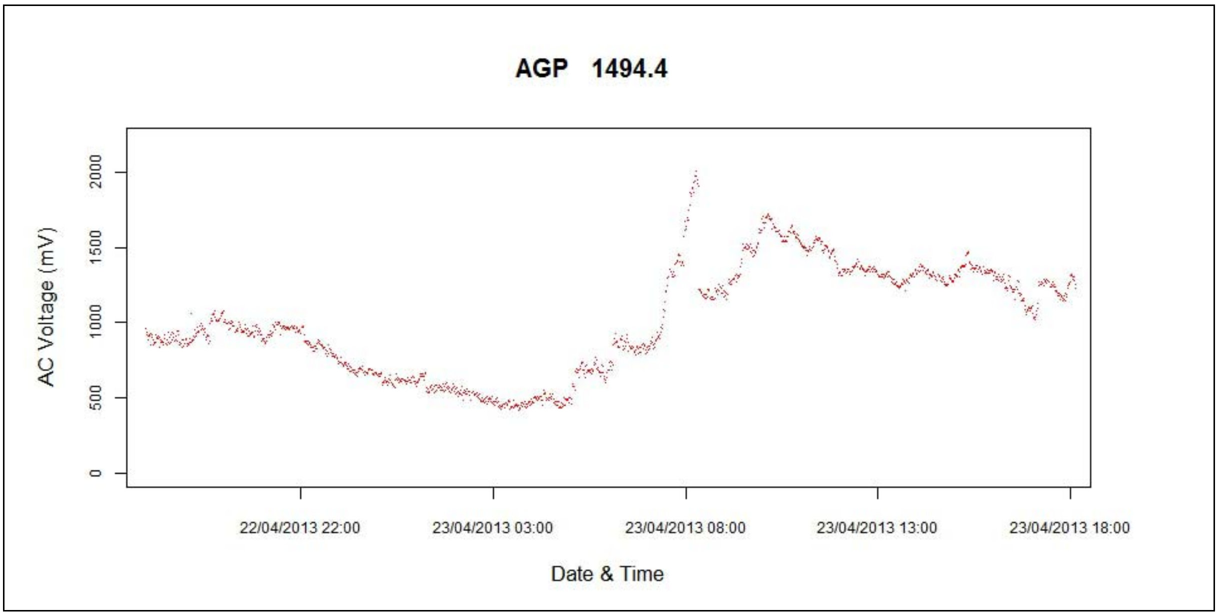


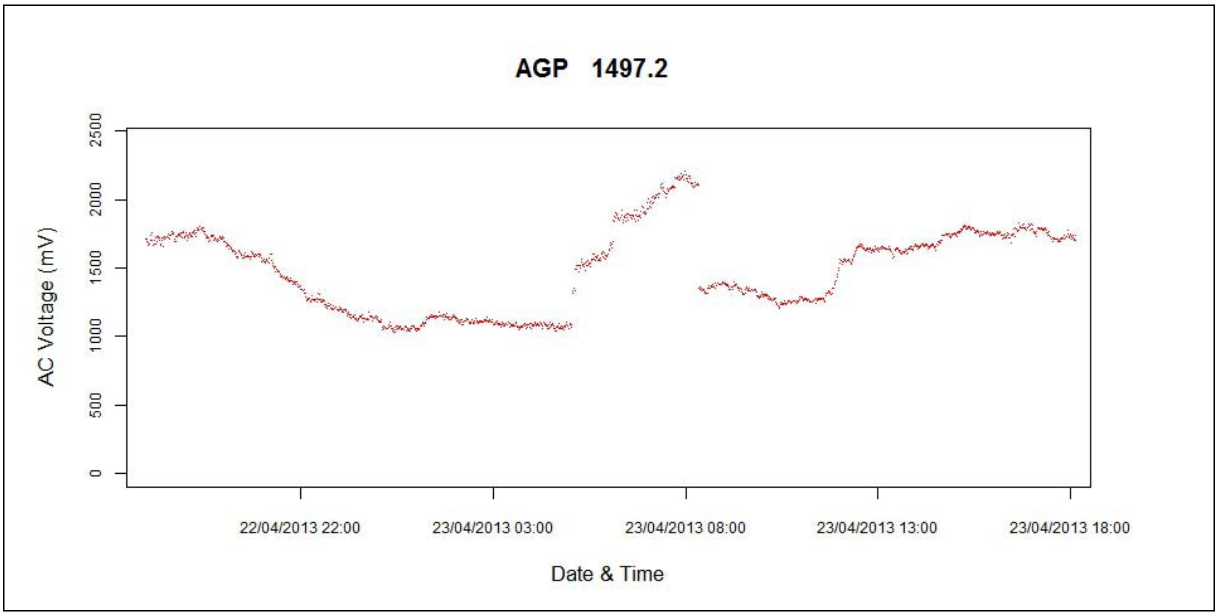

AGP 1450.7
AC Voltage (mV)
0
50
100
150
200
250
22/04/2013 22:00
23/04/2013 03:00
23/04/2013 08:00
23/04/2013 13:00
23/04/2013 18:00
Date & Time


AGP 1458
AC Voltage (mV)
0
100
200
300
400
500
22/04/2013 22:00
23/04/2013 03:00
23/04/2013 08:00
23/04/2013 13:00
23/04/2013 18:00
Date & Time


AGP 1472.8
AC Voltage (mV)
0
200
400
600
800
1000
22/04/2013 22:00
23/04/2013 03:00
23/04/2013 08:00
23/04/2013 13:00
23/04/2013 18:00
Date & Time


AGP 1488.8
AC Voltage (mV)
0
500
1000
1500
2000
22/04/2013 22:00
23/04/2013 03:00
23/04/2013 08:00
23/04/2013 13:00
23/04/2013 18:00
Date & Time


AGP 1494.4
AC Voltage (mV)
0
500
1000
1500
2000
22/04/2013 22:00
23/04/2013 03:00
23/04/2013 08:00
23/04/2013 13:00
23/04/2013 18:00
Date & Time


AGP 1497.2
AC Voltage (mV)
0
500
1000
1500
2000
2500
22/04/2013 22:00
23/04/2013 03:00
23/04/2013 08:00
23/04/2013 13:00
23/04/2013 18:00
Date & Time

Appendix 7

Results of LFI analysis for Channel Island spurline, 132 kV Katherine powerline

PRC INTERNATIONAL

Faulted Tower Data
Comments

Comments

LFI analysis - Darwin City Gate to Channel Island pipeline

Pipe diameter = 324 mm OD.
Pipeline coated with extruded PE, thickness 1.1 mm.
Coating resistance taken as 100 k ohm sq metre.
Soil resistivity 1,000 ohm cm as per readings taken at KP 1506.
Chainage 00 at Darwin City Gate.
132 kV powerline from Channel Island to Manton to Katherine.
Phase to earth fault current due to fault at Manton zone substation = 2600 A.
Earthing resistance at Darwin City Gate = 2 ohms.
Earthing resistance at KP1506 = 4 ohms.
Earthing resistance at earthing beds at Channel Island = 1.4 ohms.

File HV-CI-01.acd

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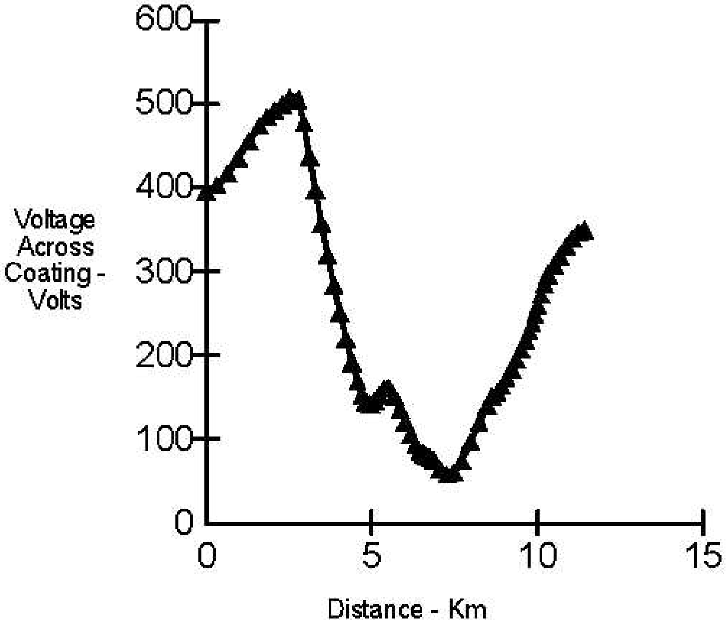
PRC INTERNATIONAL

Fault Voltage
Graph and Data



Pipe #1		Pipe #1 (cont.)		Pipe #1 (cont.)	
Distance	Volts	Distance	Volts	Distance	Volts
0.00	396.3	5.53	161.1	9.85	237.8
0.32	402.5	5.69	151.3	9.94	248.4
0.64	417.3	5.85	135.4	10.03	259.9
0.97	434.9	6.02	119.9	10.12	272.1
1.29	455.2	6.18	105.0	10.22	284.6
1.61	473.6	6.34	92.9	10.32	296.6
1.84	484.5	6.45	86.2	10.51	307.7
2.07	491.6	6.55	82.5	10.69	318.6
2.31	499.4	6.66	79.9	10.88	329.7
2.54	508.2	6.77	78.6	11.06	339.3
2.77	505.5	6.88	74.2	11.26	346.3
2.95	477.6	7.08	64.6	11.45	349.4
3.13	437.1	7.28	58.1		
3.31	396.8	7.48	60.2		
3.49	357.1	7.73	74.3		
3.67	319.1	7.99	96.4		
3.85	284.1	8.25	120.2		
4.03	251.3	8.51	139.6		
4.21	220.0	8.65	150.1		
4.39	191.4	8.79	156.8		
4.57	168.3	8.93	164.2		
4.70	152.9	9.08	172.7		
4.83	144.1	9.22	182.9		
4.96	141.3	9.37	194.5		
5.09	145.0	9.52	206.8		
5.22	152.3	9.67	218.4		
5.38	159.4	9.76	228.1		

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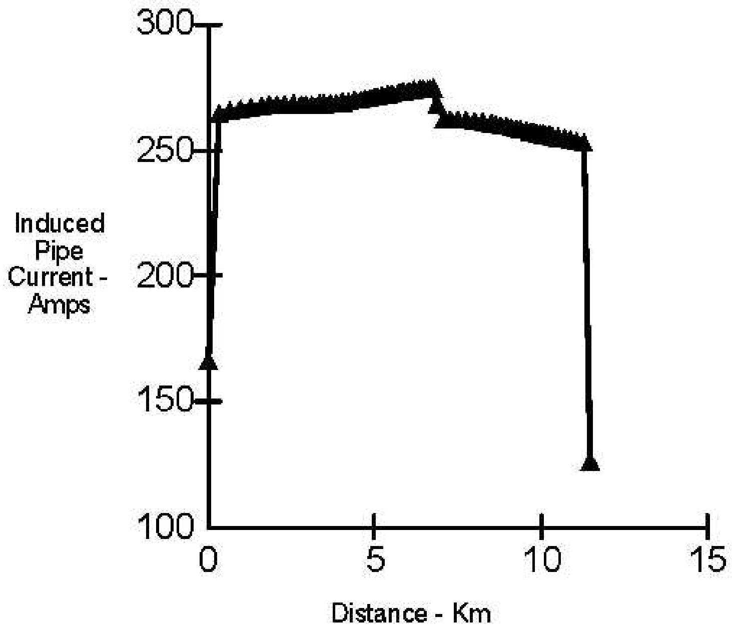
Fault Current
Graph and Data



Pipe #1		Pipe #1 (cont.)		Pipe #1 (cont.)	
Distance	Current	Distance	Current	Distance	Current
0.00	165.9	5.53	272.5	9.85	256.8
0.32	264.6	5.69	272.9	9.94	256.6
0.64	265.6	5.85	273.3	10.03	256.3
0.97	266.5	6.02	273.6	10.12	256.1
1.29	267.2	6.18	273.9	10.22	255.9
1.61	267.7	6.34	274.1	10.32	255.6
1.84	268.0	6.45	274.2	10.51	255.2
2.07	268.2	6.55	274.3	10.69	254.7
2.31	268.3	6.66	274.4	10.88	254.2
2.54	268.3	6.77	274.4	11.06	253.6
2.77	268.3	6.88	268.3	11.26	253.0
2.95	268.2	7.08	262.4	11.45	126.3
3.13	268.3	7.28	262.4		
3.31	268.3	7.48	262.2		
3.49	268.5	7.73	262.0		
3.67	268.7	7.99	261.6		
3.85	268.9	8.25	261.1		
4.03	269.1	8.51	260.5		
4.21	269.4	8.65	260.2		
4.39	269.8	8.79	259.8		
4.57	270.1	8.93	259.4		
4.70	270.4	9.08	259.0		
4.83	270.7	9.22	258.6		
4.96	271.0	9.37	258.2		
5.09	271.3	9.52	257.8		
5.22	271.7	9.67	257.3		
5.38	272.1	9.76	257.1		

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PRC INTERNATIONAL

Faulted Tower Data
T-Line Information

T-Line

	D - m	H - m	R - ohms/Km	GMR - m
Shield Wire #1	-5	25	2.24	0.0008
Shield Wire #2	5	25	2.24	0.0008

	D - m	H - m	IL - A	IR - A	Total Current
Phase Wire	0	18	0	2600	2600

	Avg Twr Sep. - m	Avg Twr Res - ohms	Faulted Twr Location
Elec. Sys Parameters	350	5	1

Arc Distance (m) 0

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PRC INTERNATIONAL

Faulted Tower Data
Pipe Information

Pipe #1

Diameter - m	Burial Depth - m	R - Kohm-m2	Thickness - m
0.324	-1.5	100	0.001

First section **is not** terminated in insulator
Last section **is** terminated in insulator

07/22/2013 - Page 5

PRC INTERNATIONAL

Faulted Tower Data
Section Information

Section	Length	Soil Res	L1 - D	L1 - A	L2 - D	L2 - A	L3 - D	L3 - A	L4 - D	L4 - A	L5 - D	L5 - A	P1 - D	P1 - A	P2 - D	P2 - A	P3 - D	P3 - A
1	322	1000	440	0									0	0				
2	322	1000	440	0									0	0				
3	322	1000	440	0									0	0				
4	322	1000	440	0									0	0				
5	322	1000	440	0									0	0				
6	232	1000	250	0									0	0				
7	232	1000	250	0									0	0				
8	232	1000	250	0									0	0				
9	232	1000	250	0									0	0				
10	232	1000	250	0									0	0				
11	180	1000	15	0									0	0				
12	180	1000	15	0									0	0				
13	180	1000	15	0									0	0				
14	180	1000	15	0									0	0				
15	180	1000	15	0									0	0				
16	180	1000	25	0									0	0				
17	180	1000	25	0									0	0				
18	180	1000	25	0									0	0				
19	180	1000	25	0									0	0				
20	180	1000	25	0									0	0				
21	130	1000	20	0									0	0				
22	130	1000	20	0									0	0				
23	130	1000	20	0									0	0				
24	130	1000	20	0									0	0				
25	130	1000	20	0									0	0				
26	155	1000	-50	0									0	0				
27	155	1000	-50	0									0	0				
28	162	1000	-200	0									0	0				
29	162	1000	-200	0									0	0				
30	162	1000	-200	0									0	0				
31	162	1000	-200	0									0	0				
32	162	1000	-200	0									0	0				
33	107	1000	-150	0									0	0				
34	107	1000	-150	0									0	0				
35	107	1000	-150	0									0	0				
36	107	1000	-150	0									0	0				
37	107	1000	-150	0									0	0				
38	203	1000	-300	0									0	0				
39	203	1000	-300	0									0	0				
40	203	1000	-300	0									0	0				
41	250	1000	-450	0									0	0				
42	257	1000	-200	0									0	0				
43	257	1000	-200	0									0	0				
44	257	1000	-200	0									0	0				
45	143	1000	80	0									0	0				
46	143	1000	80	0									0	0				
47	143	1000	65	0									0	0				
48	143	1000	65	0									0	0				
49	143	1000	65	0									0	0				
50	150	1000	80	0									0	0				
51	150	1000	80	0									0	0				
52	150	1000	80	0									0	0				
53	90	1000	30	0									0	0				
54	90	1000	30	0									0	0				
55	90	1000	30	0									0	0				
56	90	1000	30	0									0	0				
57	90	1000	30	0									0	0				
58	100	1000	50	0									0	0				
59	100	1000	50	0									0	0				
60	185	1000	160	0									0	0				
61	185	1000	160	0									0	0				
62	185	1000	160	0									0	0				
63	185	1000	160	0									0	0				
64	195	1000	260	0									0	0				
65	195	1000	260	0									0	0				

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PRC INTERNATIONAL

Faulted Tower Data
Mitigation & Bond Info

Sec/Node	P1-NodeR	P1-AnodeDR	P1-ParWire	P2&1-Bond	P2-NodeR	P2-AnodeDR	P2-ParWire	P3&2-Bond	P3-NodeR	P3-AnodeDR	P3-ParWire	P1&3-Bond
1	2											
2												
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66	1.4											

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Appendix 8

Results of LFI analysis for Channel Island spurline, 132 kV Hudson Creek powerline

PRC INTERNATIONAL

Faulted Tower Data
Comments

Comments

LFI analysis - Darwin City Gate to Channel Island pipeline

Pipe diameter = 324 mm OD.
Pipeline coated with extruded PE, thickness 1.1 mm.
Coating resistance taken as 100 k ohm sq metre.
Soil resistivity 1,000 ohm cm as per readings taken at KP 1506.
Chainage 00 at Darwin City Gate.
132 kV powerline from Channel Island to Hudson Creek.
Phase to earth fault current due to fault at Hudson Creek = 6000 A.
Earthing resistance at Darwin City Gate = 2 ohms.
Earthing resistance at KP1506 = 4 ohms.
Earthing resistance at earthing beds at Channel Island = 1.4 ohms.

File HV-CH-01.acd

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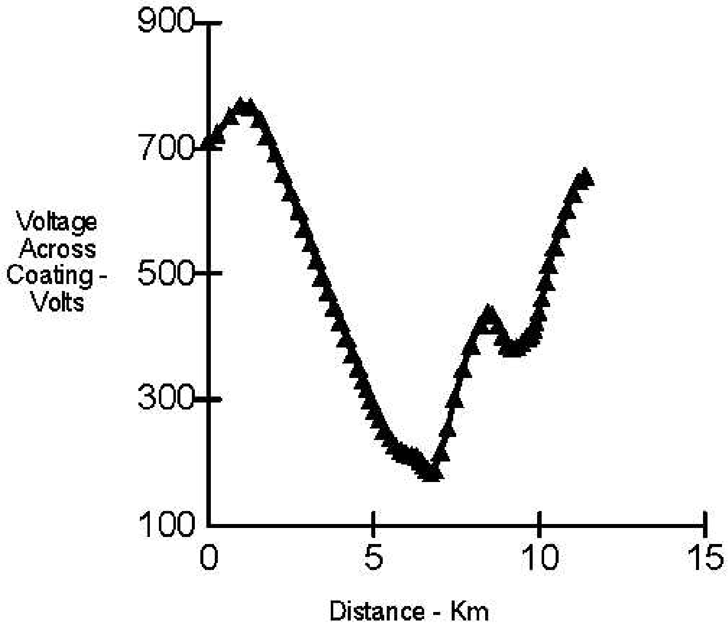
PRC INTERNATIONAL

Fault Voltage
Graph and Data



Pipe #1		Pipe #1 (cont.)		Pipe #1 (cont.)	
Distance	Volts	Distance	Volts	Distance	Volts
0.00	709.9	5.49	237.2	9.81	410.5
0.25	722.9	5.65	226.6	9.90	422.6
0.66	750.4	5.81	219.2	9.99	439.5
0.97	768.2	5.98	213.9	10.08	461.1
1.27	765.4	6.14	211.2	10.18	486.1
1.57	745.3	6.30	208.5	10.28	513.7
1.80	718.4	6.41	202.6	10.47	542.5
2.03	690.2	6.51	195.1	10.65	571.7
2.27	660.5	6.62	188.6	10.84	600.9
2.50	629.6	6.73	183.1	11.02	626.8
2.73	599.6	6.84	188.7	11.22	646.5
2.91	572.9	7.04	216.0	11.41	655.3
3.09	547.8	7.24	255.3		
3.27	522.2	7.44	301.3		
3.45	496.2	7.69	349.9		
3.63	470.6	7.95	387.2		
3.81	445.8	8.21	418.0		
3.99	421.5	8.47	437.8		
4.17	396.9	8.61	433.6		
4.35	372.1	8.75	417.2		
4.53	349.3	8.89	400.7		
4.66	331.0	9.04	387.1		
4.79	314.8	9.18	380.6		
4.92	298.7	9.33	382.4		
5.05	282.8	9.48	390.3		
5.18	266.9	9.63	398.6		
5.34	251.2	9.72	403.7		

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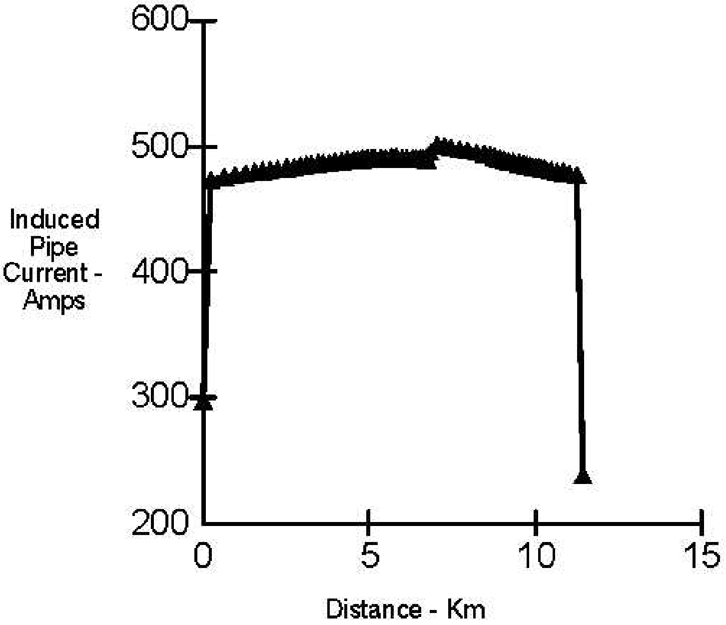
PRC INTERNATIONAL

Fault Current
Graph and Data



Pipe #1		Pipe #1 (cont.)		Pipe #1 (cont.)	
Distance	Current	Distance	Current	Distance	Current
0.00	296.6	5.49	490.7	9.81	484.1
0.25	472.8	5.65	490.8	9.90	483.6
0.66	475.1	5.81	490.8	9.99	483.1
0.97	476.6	5.98	490.7	10.08	482.6
1.27	477.9	6.14	490.6	10.18	482.1
1.57	479.0	6.30	490.4	10.28	481.6
1.80	479.9	6.41	490.3	10.47	480.7
2.03	480.7	6.51	490.2	10.65	479.8
2.27	481.6	6.62	490.0	10.84	478.8
2.50	482.5	6.73	489.8	11.02	477.7
2.73	483.4	6.84	494.8	11.22	476.5
2.91	484.0	7.04	500.6	11.41	237.9
3.09	484.7	7.24	500.0		
3.27	485.3	7.44	499.2		
3.45	485.9	7.69	498.1		
3.63	486.6	7.95	496.7		
3.81	487.1	8.21	495.2		
3.99	487.7	8.47	493.4		
4.17	488.2	8.61	492.4		
4.35	488.7	8.75	491.3		
4.53	489.1	8.89	490.3		
4.66	489.4	9.04	489.3		
4.79	489.7	9.18	488.3		
4.92	489.9	9.33	487.3		
5.05	490.2	9.48	486.3		
5.18	490.4	9.63	485.3		
5.34	490.5	9.72	484.7		

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PRC INTERNATIONAL

Faulted Tower Data
T-Line Information

T-Line

	D - m	H - m	R - ohms/Km	GMR - m
Shield Wire #1	-5	25	2.24	0.0008
Shield Wire #2	5	25	2.24	0.0008

	D - m	H - m	IL - A	IR - A	Total Current
Phase Wire	0	18	0	6000	6000

	Avg Twr Sep. - m	Avg Twr Res - ohms	Faulted Twr Location
Elec. Sys Parameters	350	5	1

Arc Distance (m) 0.5

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Faulted Tower Data
Pipe Information

Pipe #1

Diameter - m	Burial Depth - m	R - Kohm-m2	Thickness - m
0.324	-1.5	100	0.001

First section **is not** terminated in insulator
Last section **is** terminated in insulator

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PRC INTERNATIONAL

Faulted Tower Data
Section Information

Section	Length	Soil Res	L1 - D	L1 - R	L2 - D	L2 - R	L3 - D	L3 - R	L4 - D	L4 - R	L5 - D	L5 - R	P1 - D	P1 - R	P2 - D	P2 - R	P3 - D	P3 - R
1	250	1000	-930	0									0	0				
2	410	1000	-500	0									0	0				
3	310	1000	-350	0									0	0				
4	300	1000	-230	0									0	0				
5	300	1000	-140	0									0	0				
6	232	1000	-125	0									0	0				
7	232	1000	-125	0									0	0				
8	232	1000	-125	0									0	0				
9	232	1000	-125	0									0	0				
10	232	1000	-125	0									0	0				
11	180	1000	-130	0									0	0				
12	180	1000	-130	0									0	0				
13	180	1000	-130	0									0	0				
14	180	1000	-130	0									0	0				
15	180	1000	-130	0									0	0				
16	180	1000	-145	0									0	0				
17	180	1000	-145	0									0	0				
18	180	1000	-145	0									0	0				
19	180	1000	-145	0									0	0				
20	180	1000	-145	0									0	0				
21	130	1000	-160	0									0	0				
22	130	1000	-160	0									0	0				
23	130	1000	-160	0									0	0				
24	130	1000	-160	0									0	0				
25	130	1000	-160	0									0	0				
26	155	1000	-175	0									0	0				
27	155	1000	-175	0									0	0				
28	162	1000	-200	0									0	0				
29	162	1000	-200	0									0	0				
30	162	1000	-200	0									0	0				
31	162	1000	-200	0									0	0				
32	162	1000	-200	0									0	0				
33	107	1000	-150	0									0	0				
34	107	1000	-150	0									0	0				
35	107	1000	-150	0									0	0				
36	107	1000	-150	0									0	0				
37	107	1000	-150	0									0	0				
38	203	1000	-300	0									0	0				
39	203	1000	-300	0									0	0				
40	203	1000	-300	0									0	0				
41	250	1000	-450	0									0	0				
42	257	1000	-200	0									0	0				
43	257	1000	-200	0									0	0				
44	257	1000	-200	0									0	0				
45	143	1000	80	0									0	0				
46	143	1000	80	0									0	0				
47	143	1000	65	0									0	0				
48	143	1000	65	0									0	0				
49	143	1000	65	0									0	0				
50	150	1000	80	0									0	0				
51	150	1000	80	0									0	0				
52	150	1000	80	0									0	0				
53	90	1000	30	0									0	0				
54	90	1000	30	0									0	0				
55	90	1000	30	0									0	0				
56	90	1000	30	0									0	0				
57	90	1000	30	0									0	0				
58	100	1000	50	0									0	0				
59	100	1000	50	0									0	0				
60	185	1000	160	0									0	0				
61	185	1000	160	0									0	0				
62	185	1000	160	0									0	0				
63	185	1000	160	0									0	0				
64	195	1000	260	0									0	0				
65	195	1000	260	0									0	0				

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Faulted Tower Data
Mitigation & Bond Info

Sec/Node	P1-NodeR	P1-AnodeDR	P1-ParWire	P2&1-Bond	P2-NodeR	P2-AnodeDR	P2-ParWire	P3&2-Bond	P3-NodeR	P3-AnodeDR	P3-ParWire	P1&3-Bond
1	2											
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
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38	4											
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66	1.4											

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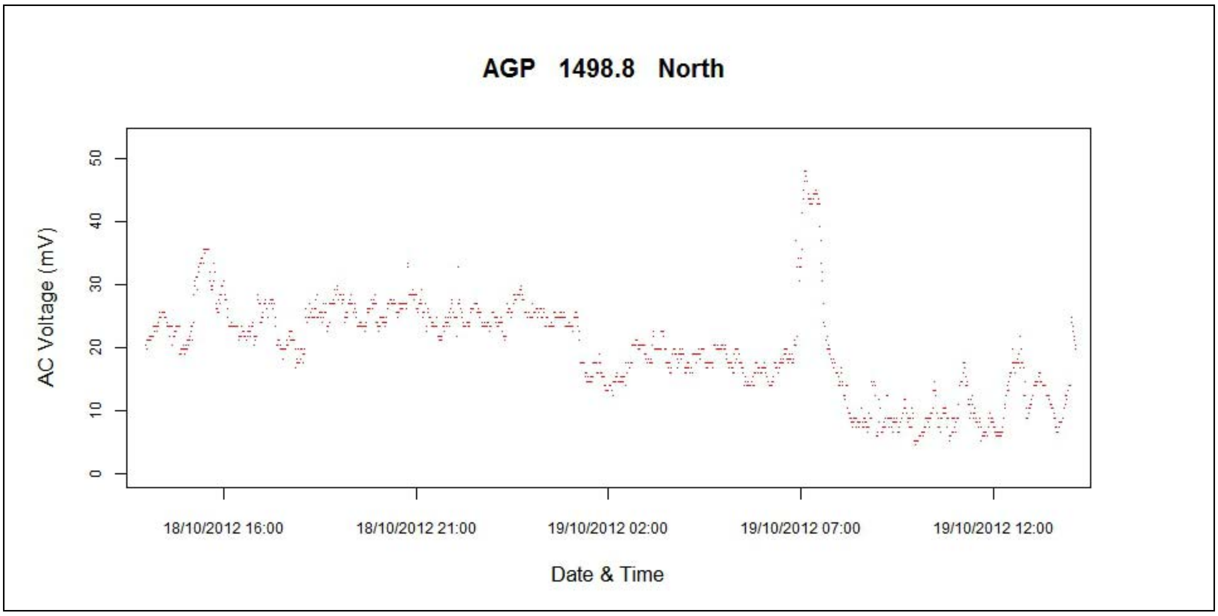
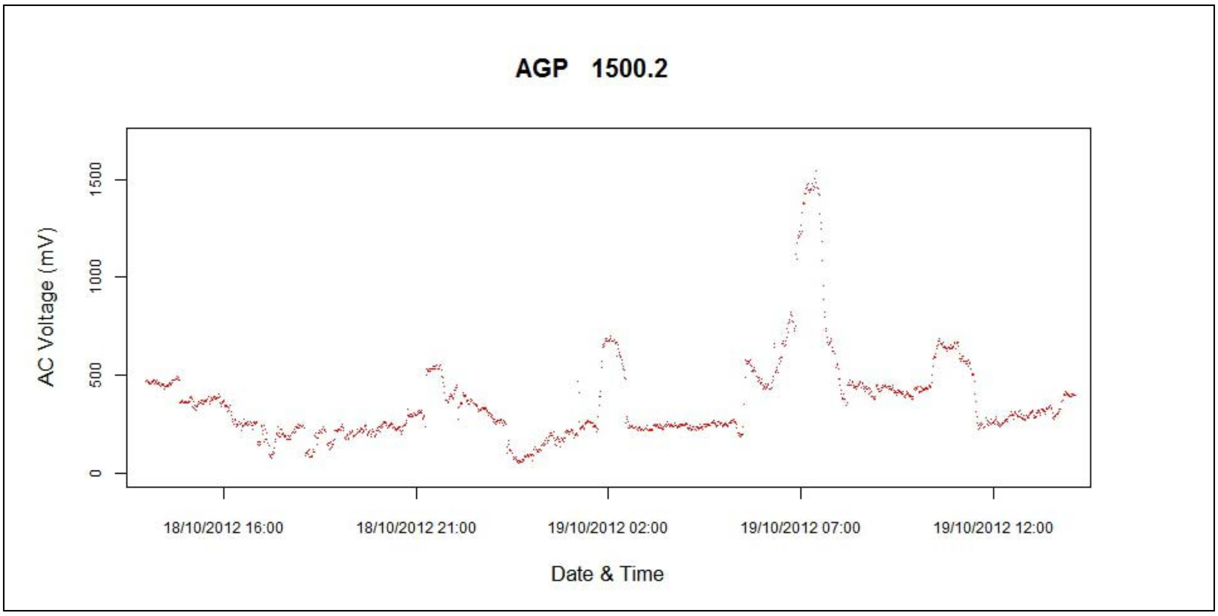
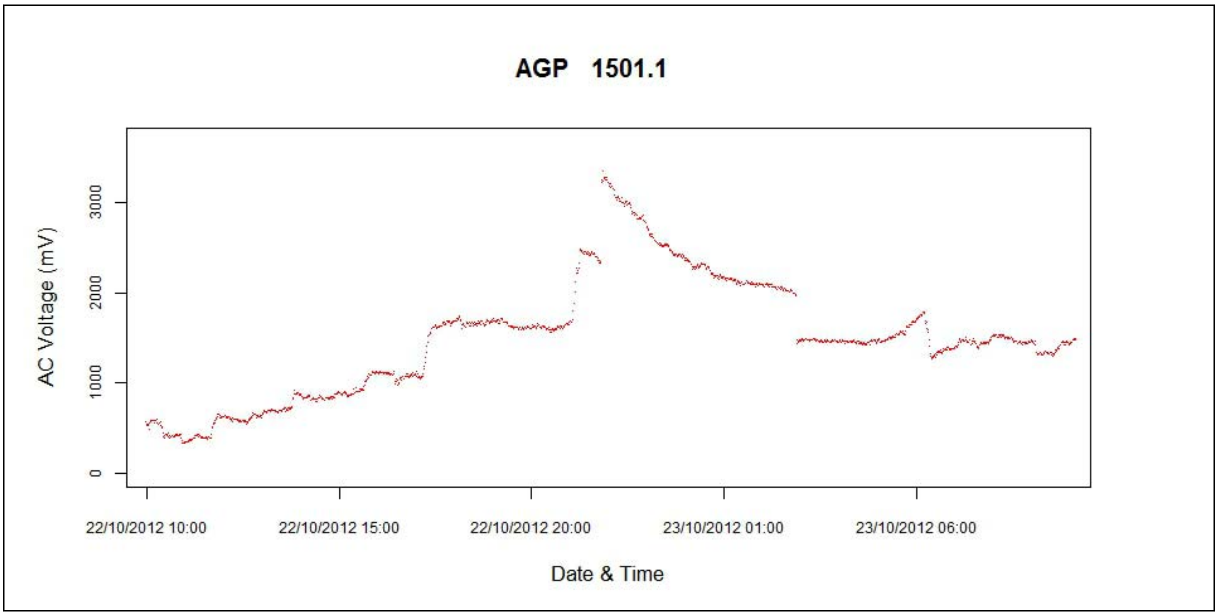
Appendix 9

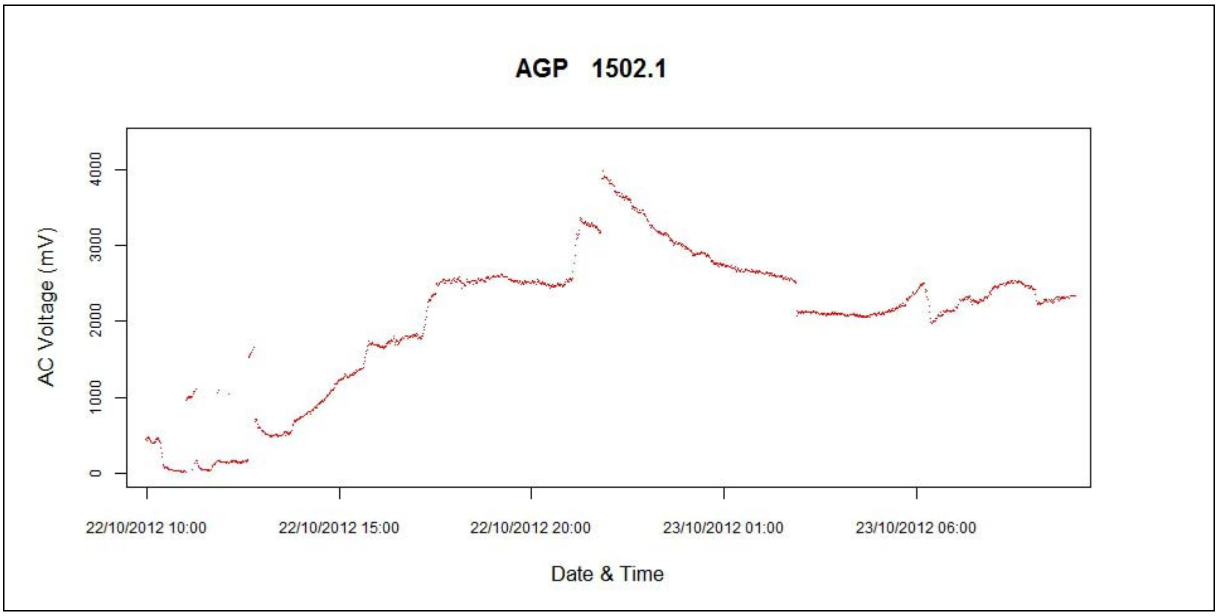
Darwin City Gate to Channel Island spur pipeline
AC Recording Data Logger Charts

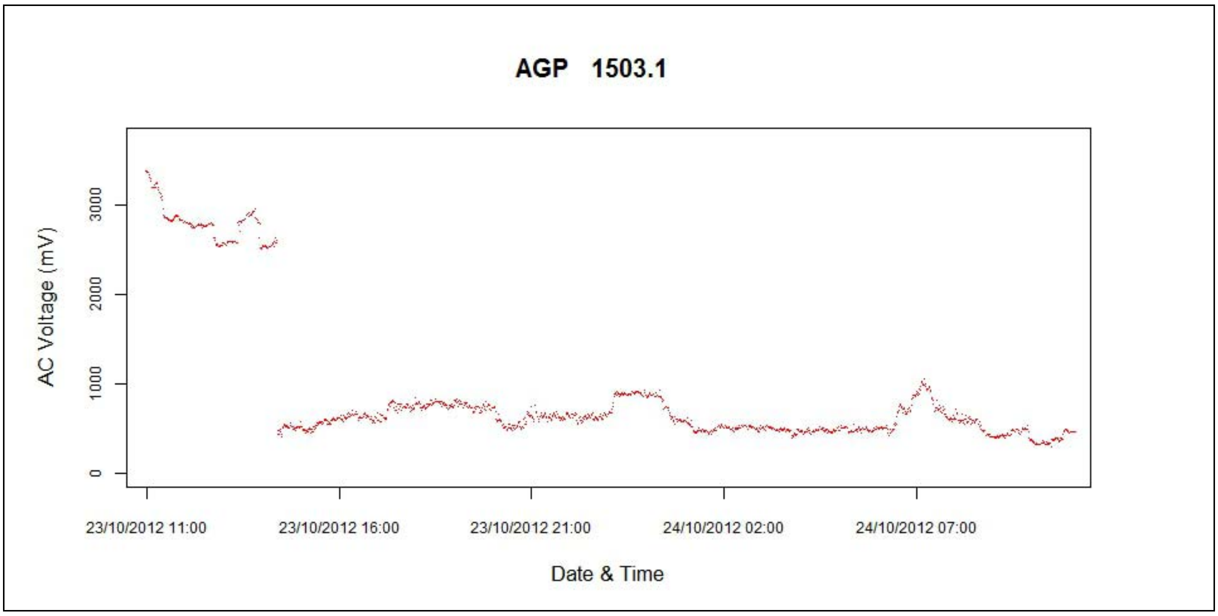
Data logger recordings were taken at KPs 1498.8, 1500.2, 1501.1, 1502.1, 1503.1, 1504.1, 1504.9. 1505, 1509 and 1510.8 as shown on each chart respectively.

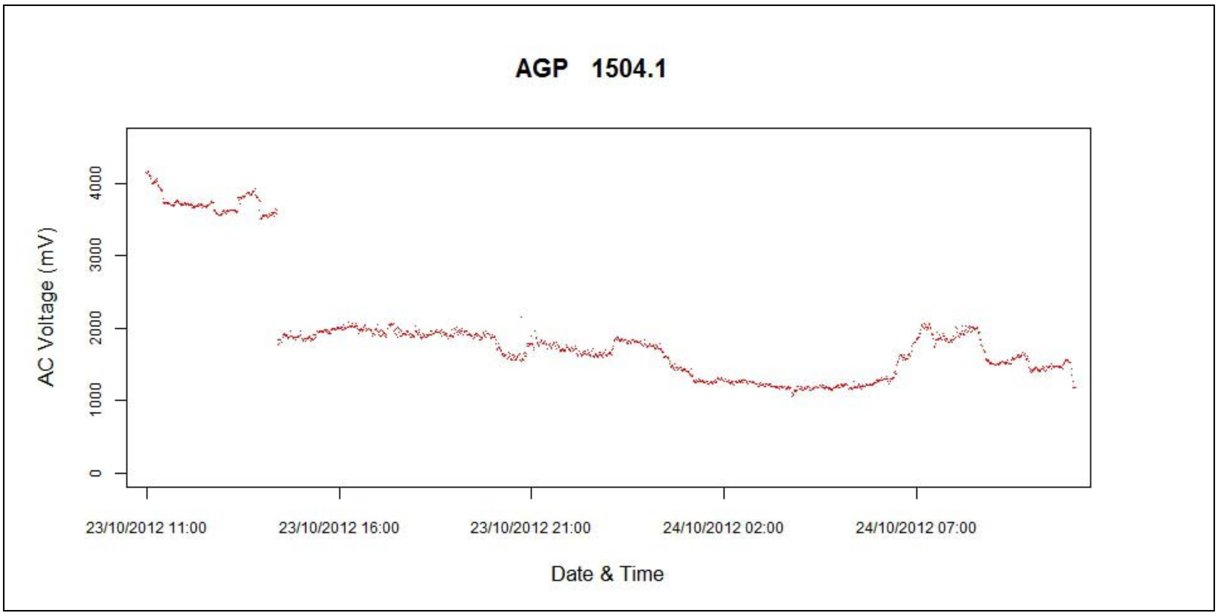


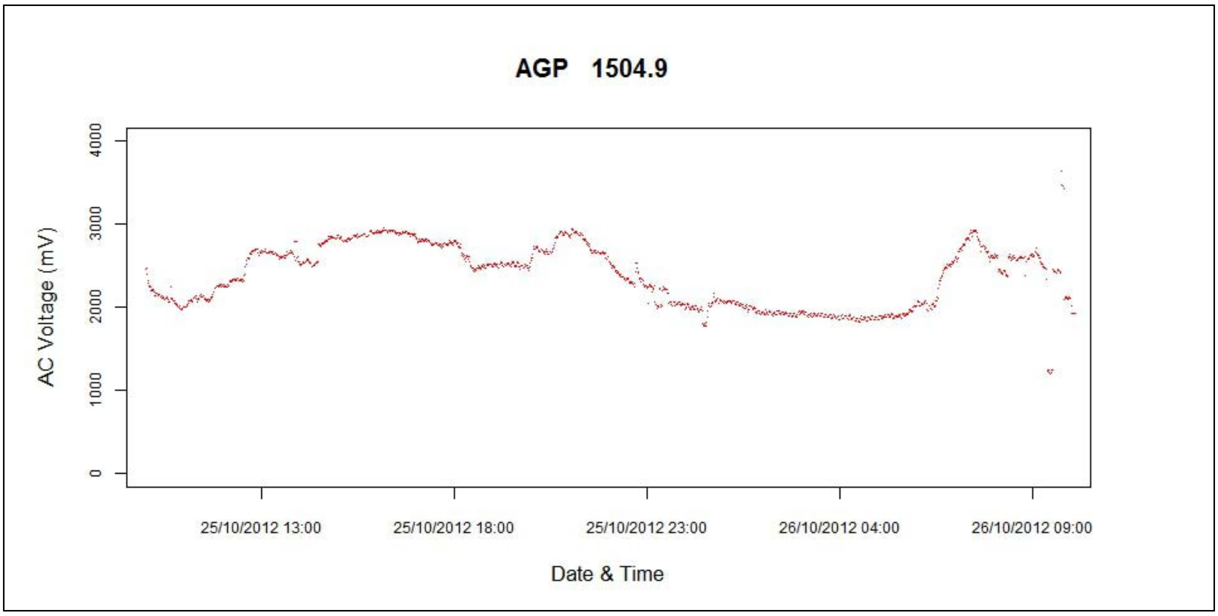


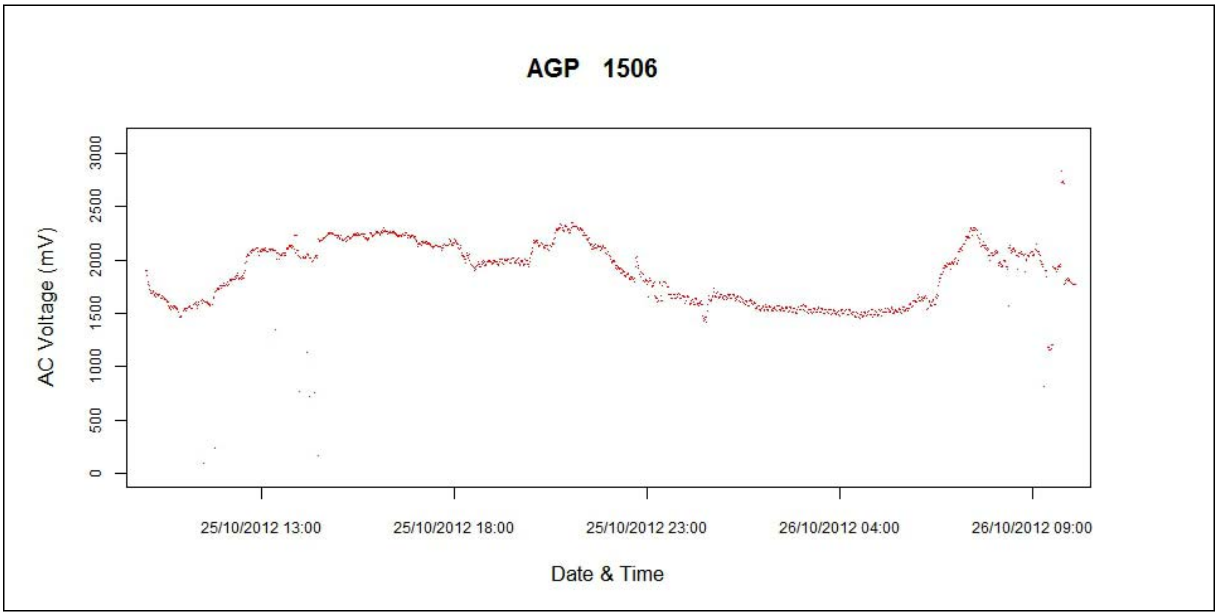

AGP 1501.1
AC Voltage (mV)
0
1000
2000
3000
22/10/2012 10:00
22/10/2012 15:00
22/10/2012 20:00
23/10/2012 01:00
23/10/2012 06:00
Date & Time

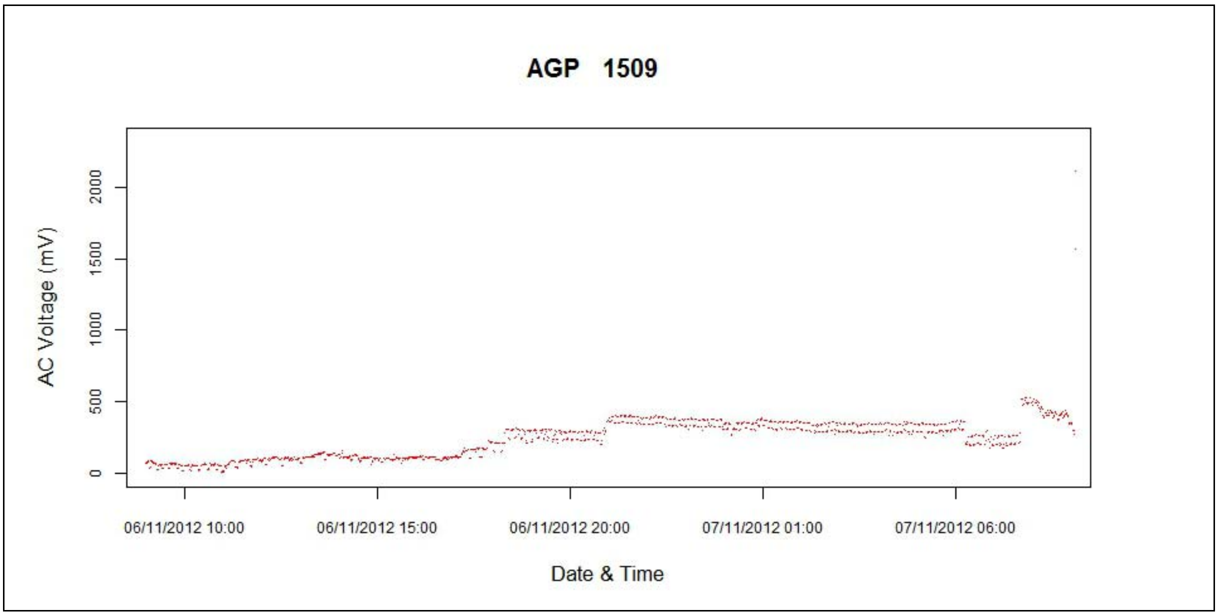

AGP 1502.1
AC Voltage (mV)
0
1000
2000
3000
4000
22/10/2012 10:00
22/10/2012 15:00
22/10/2012 20:00
23/10/2012 01:00
23/10/2012 06:00
Date & Time

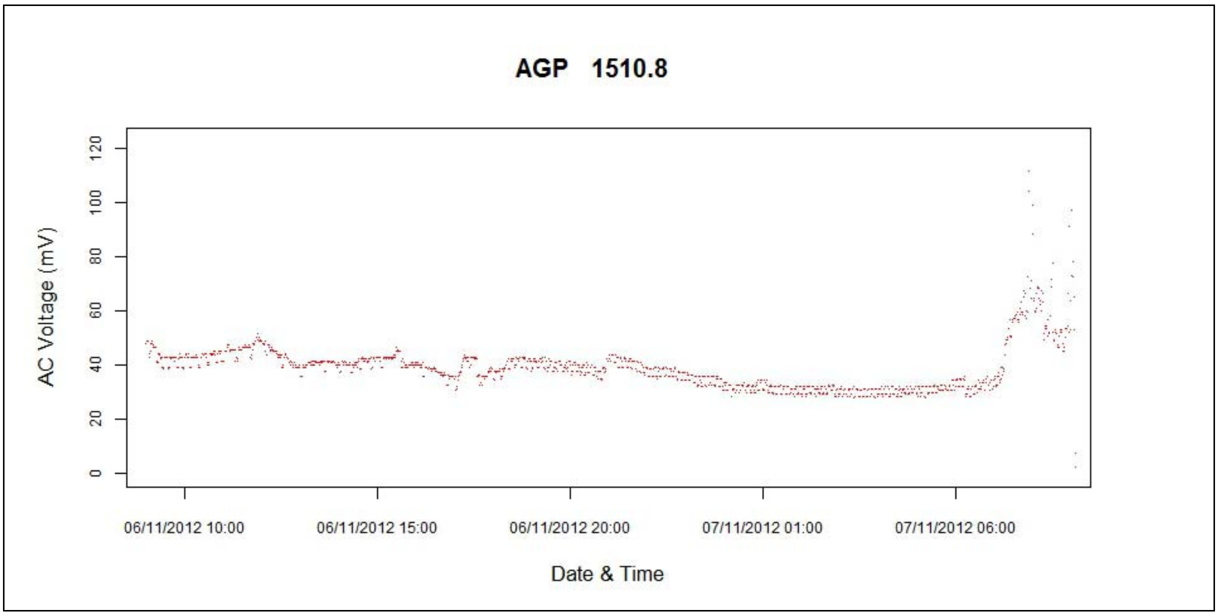

AGP 1503.1
AC Voltage (mV)
0
1000
2000
3000
23/10/2012 11:00
23/10/2012 16:00
23/10/2012 21:00
24/10/2012 02:00
24/10/2012 07:00
Date & Time


AGP 1504.1
AC Voltage (mV)
0
1000
2000
3000
4000
23/10/2012 11:00
23/10/2012 16:00
23/10/2012 21:00
24/10/2012 02:00
24/10/2012 07:00
Date & Time


AGP 1504.9
AC Voltage (mV)
0
1000
2000
3000
4000
25/10/2012 13:00
25/10/2012 18:00
25/10/2012 23:00
26/10/2012 04:00
26/10/2012 09:00
Date & Time

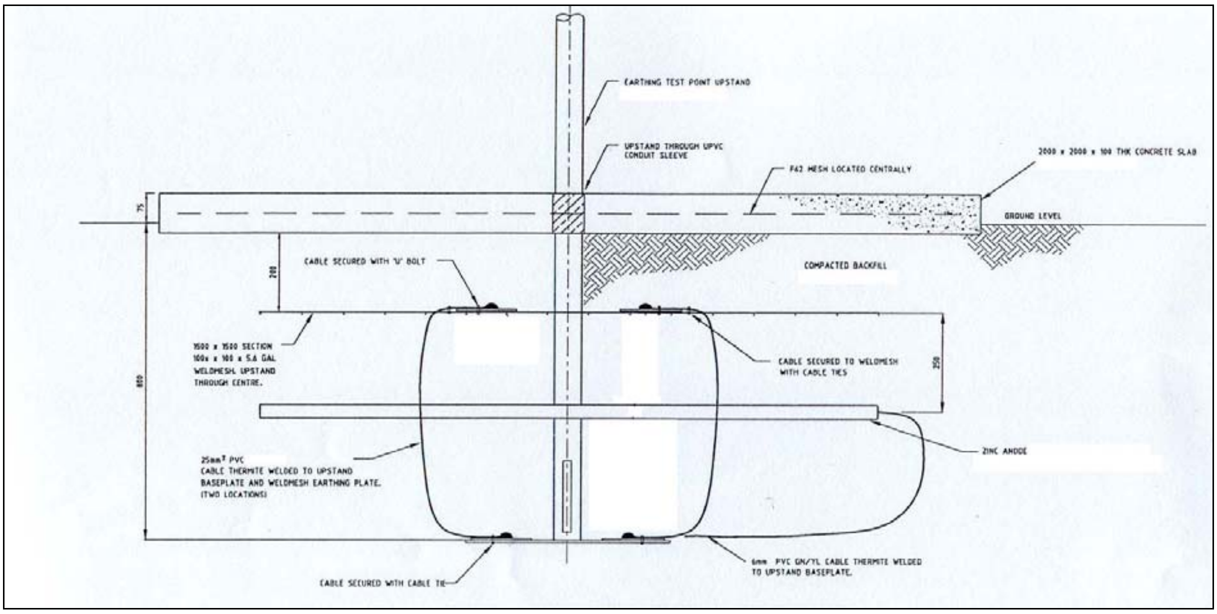

AGP 1506
AC Voltage (mV)
0
500
1000
1500
2000
2500
3000
25/10/2012 13:00
25/10/2012 18:00
25/10/2012 23:00
26/10/2012 04:00
26/10/2012 09:00
Date & Time


AGP 1509
AC Voltage (mV)
0
500
1000
1500
2000
06/11/2012 10:00
06/11/2012 15:00
06/11/2012 20:00
07/11/2012 01:00
07/11/2012 06:00
Date & Time

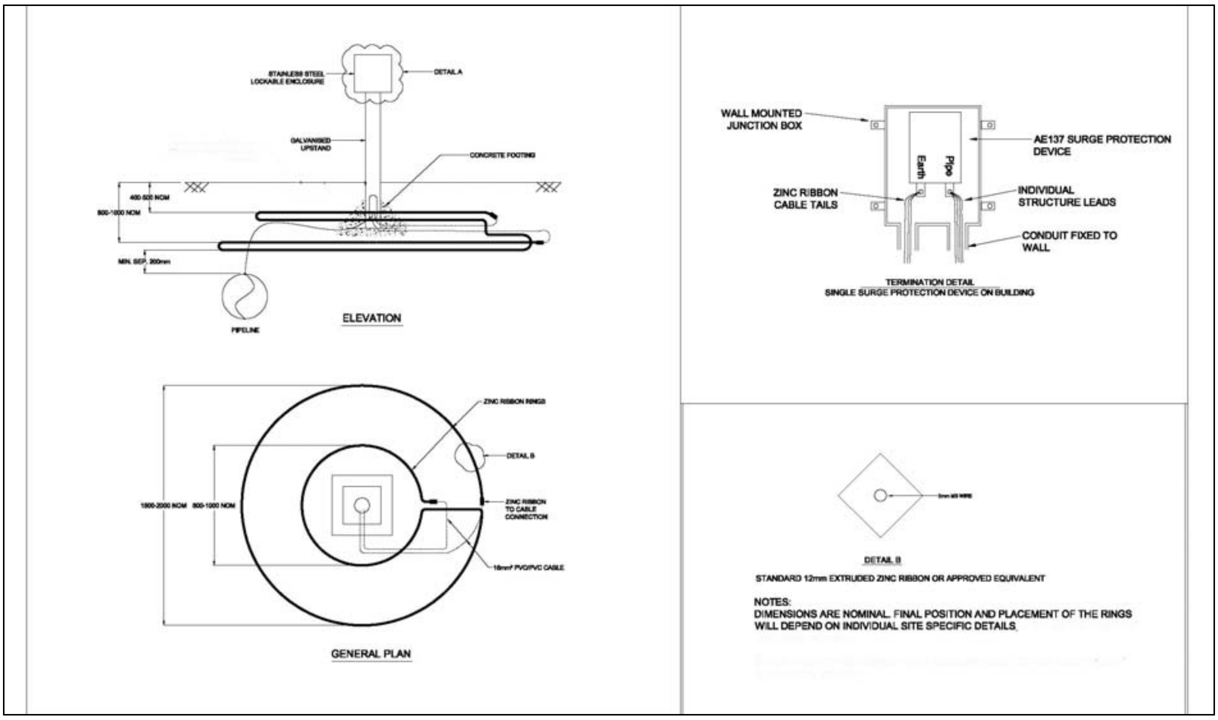

AGP 1510.8
AC Voltage (mV)
0
20
40
60
80
100
120
06/11/2012 10:00
06/11/2012 15:00
06/11/2012 20:00
07/11/2012 01:00
07/11/2012 06:00
Date & Time

Appendix 10

Outline schematic sketches of safety installations for test points.



Equipotential grid - typical schematic outline



Grading ring - typical schematic outline

<u>Note:</u> In most circumstances these installations should be decoupled from the pipeline via devices that block current flow at low DC voltages. Typically these decoupling devices do not conduct current at voltages below about 2 V. This prevents consumption of the grid or ring by providing CP to the pipeline, or loss of pipeline CP by providing protection to the grid or ring. The dissipation rating of the device must be appropriate to the magnitude and duration of current flowing through it under powerline fault conditions.

Addendum 1

ARGON safety assessment – Katherine offtake

AS/NZS 4853 adopts a risk assessment process that maintains the risk of fatality within acceptable limits. The process is described in ENA EG-0. The probabilistic method calculations may be performed manually; however the ARGON software program available with ENA EG-0 is approved as a tool for assessing and documenting the risk assessment process.

Input data for Katherine offtake:

The typical maintenance activities involving personnel contact at this site have been taken as follows:

- CP pipe to soil potential measurement: frequency = once per year, maximum contact duration = two minutes.
- Valve check (complete): frequency = every six months, maximum contact duration = five minutes (open bypass valves, 4 total, close MLV, open MLV, close bypass valves).
- Valve check (partial): frequency = every two months, maximum contact duration = two minutes (partially cycle all valves).
- Gear box maintenance: frequency = every five years, contact duration = one hour.
- Valve sealing and flushing: frequency = every five years, contact duration = three minutes.
- Emergency operation: approximately once every 25 years, maximum contact duration = ten minutes.

APA Group has advised that the above values should only be used as a guide at this point. Confirmation of frequency / duration would need to be obtained from Operations during a risk assessment workshop. The most severe of the above (Valve check – partial) is shown in the ARGON assessment on the following pages.

The electrical parameters have been based on typical scenario data in AS/NZS 4853, together with indicative information from discussions with PowerWater Corporation. This data should be further reviewed with PowerWater Corporation to check its applicability.

- Fault frequency on powerline section: ten phase to earth faults per annum
- Fault duration on powerline section: 0.3 seconds

ARGON - SAFETY ASSESSMENT REPORT

Report Generated On : 26 August 2013

Report Generated By : Geoff Cope

from : Geoff Cope & Associates Pty Ltd

Design Location : Katherine offtake, AGP

INTRODUCTION

Individual Probability of Fatality

This report outlines the results of a risk-based safety criteria assessment study for the above location. The analysis is based on the fact that a fatality due to contact with an external voltage can only occur if both a person is present when a fault occurs and the touch (or step) voltage generated is sufficient to allow a large enough current to pass through the body for sufficient time to cause fibrillation of the heart muscle. The probability that an individual will be present and in contact with an item at the same time that the item is affected by a fault is defined as the Probability of Coincidence (Pcoinc). The probability that the heart will enter ventricular fibrillation due to contact with an external voltage is the Probability of Fibrillation (Pfibrillation). This situation can be described by the following simple equation:

$$P_{fatality} = P_{coinc} * P_{fibrillation}$$

The probability of coincidence has been calculated using contact and fault data as detailed in this report. The probability of fibrillation has been calculated using the impedance and applied voltage / clearing time information as detailed in this report.

The calculation of the probability of fatality allows the design to be classified according to accepted risk targets (1e-6 to 1e-4) as either negligible risk, intermediate risk or intolerable risk.

Design Compliance

Designs with low risk determination are accepted and the attached design curve(s) may be used at locations with similar contact, fault and series impedance characteristics. Designs which are determined as high risk are not acceptable and there is no valid design curve available until mitigation results in a compliant design. Designs placed in the intermediate risk range may be considered compliant as a result of applying the ALARA (As Low As Reasonably Achievable) principle. For designs of this type, documentation is supplied at the end of this report outlining the justification.

The following information outlines the design assumptions and classifies the compliance of the design.

COINCIDENCE PROBABILITY

Access / Fault Assumptions

Scenario Name User Defined Assumptions

Description Enter Contact data as required

				Individual	
Fault Frequency	10	*per year*	**Contact Frequency**	6	*per Year*
Fault Duration	0.3	*seconds*	**Contact Duration**	120	*seconds*

Coincidence Reduction

Concidence Reduction Method None

Concidence Reduction Factor 1

Individual Coincidence Probability = 2.29e-4

FIBRILLATION PROBABILITY

Assumptions

Current Path	Touch Voltage	
Footwear	Standard Footwear	
Wet / Dry ?	Dry	
Soil Resistivity	50	*Ω-m*
Applied Voltage	1009	*volts*
Fault Duration	0.3	*seconds*

Surface Layer

Type	Crushed Rock	
Resistivity	3000	*Ω-m*
Depth	0.1	*metres*
Flashover Voltage	Not Specified	*volts*

Fibrillation Probability = 0.0044

RISK DETERMINATION

Individual

Risk Zone : Negligible

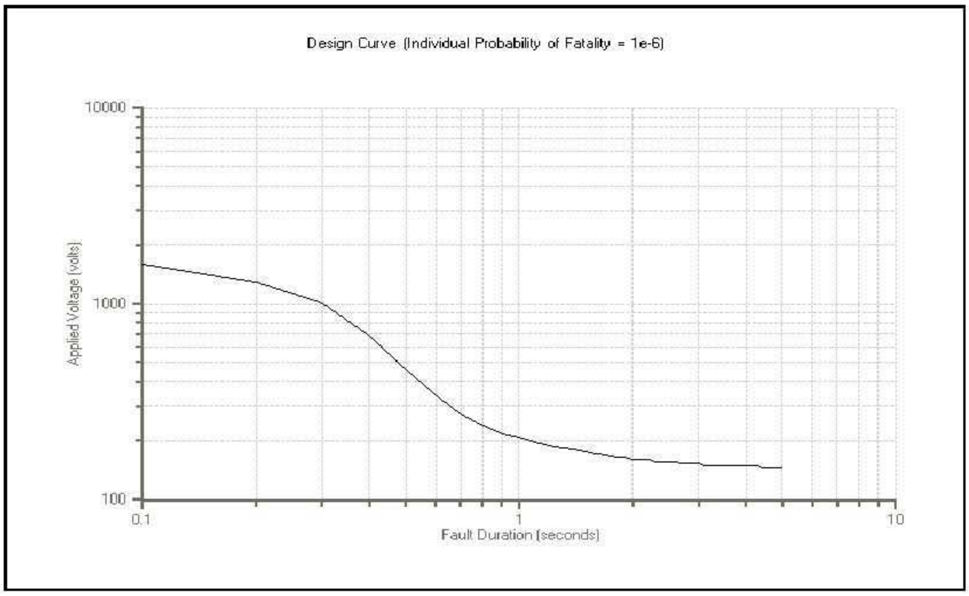
Probability of Fatality = 1e-6

Argon Version : 3.4.0.0 Calculator Version : 2.0.0.0 Page 2 of 4

DESIGN CURVE

This curve is valid for designs which have contact, fault, and series resistance characteristics similar to those outlined in this report. Fault duration need not remain the same.

Individual



RISK MITIGATION COMMENTS

No additional mitigation comments provided.

SUMMARY

Based on the information supplied in this report, the design is considered to be **COMPLIANT**

Argon Version : 3.4.0.0 Calculator Version : 2.0.0.0 Page 3 of 4

APPLICATION NOTES

Surface Soil Resistivity

Surface soil resistivity has a significant effect on the current that can pass through a body. The effect of soil resistivity is linear with the effect on the body and results can be interpolated linearly between two resistivities to provide the effect at the required resistivity when undertaking Argon based analysis.

Footwear

Appropriate footwear can significantly reduce the current that can pass through a body. Under dry conditions any enclosed leather or non-conductive rubber or plastic footwear in good condition is as effective as electrical safety boots in reducing the risk. Without such footwear the risk is equivalent to bare feet. Under wet conditions appropriate gum boots in good condition are as effective as electrical safety boots in dry conditions. Without such gum boots in wet conditions the risk is as with bare feet.

Appropriate gum boots are those which pass the following test to ensure that material from which they are made is adequately insulating:

> Fill the boot to approximately 90% of it's height with salt water and place it in a container of salt water that reaches the same water level. The resistance between electrodes inserted in the water inside the boot and outside of the boot should be determined with a high voltage resistance tester. The resistance should not be less than 1 mega ohm.

Gum boots should be maintained in good condition and replaced if any spits or cracks appear.

Surface Layers

Crushed Rock

Crushed Rock is only considered effective when installed within a secured area. It commonly serves multiple roles, including series resistance, vehicle driveway and walkway, and weed control layer. Therefore, its specification must consider electrical properties and trafficability. It is insufficient to leave the specification open as quarries may provide material that has too large a range of gravel size (i.e. too many fines (poor electrical quality), and too large size (poor trafficability)), and poor electrical resistivity performance. A typical specification would include figures such as:

- Installed depth: At least 100mm.
- Gravel size: 30 – 50 mm
- Electrical properties: 3000 Ω-m

Prior to accepting delivery of the full consignment of material some utilities carry out a brief testing process [see ENA EG-0].

NOTE: Surface layer materials exhibit a wide range of electrical properties both initially and over time, and any design requiring their use for safety reasons should take care to ensure the installation matches the required specification initially and on an ongoing basis

Addendum 2

ARGON safety assessment – Berry Springs MLV (KP 1486.5)

AS/NZS 4853 adopts a risk assessment process that maintains the risk of fatality within acceptable limits. The process is described in ENA EG-0. The probabilistic method calculations may be performed manually; however the ARGON software program available with ENA EG-0 is approved as a tool for assessing and documenting the risk assessment process.

Input data for Berry Spring MLV:

The typical maintenance activities involving personnel contact at this site have been taken as follows:

- CP pipe to soil potential measurement: frequency = once per year, maximum contact duration = two minutes.
- Valve check (complete): frequency = every six months, maximum contact duration = five minutes (open bypass valves, 4 total, close MLV, open MLV, close bypass valves).
- Valve check (partial): frequency = every two months, maximum contact duration = two minutes (partially cycle all valves).
- Gear box maintenance: frequency = every five years, contact duration = one hour.
- Valve sealing and flushing: frequency = every five years, contact duration = three minutes.
- Emergency operation: approximately once every 25 years, maximum contact duration = ten minutes.

APA Group has advised that the above values should only be used as a guide at this point. Confirmation of frequency / duration would need to be obtained from Operations during a risk assessment workshop. The most severe of the above (Valve check – partial) is shown in the ARGON assessment on the following pages.

The electrical parameters have been based on typical scenario data in AS/NZS 4853, with a factor of 10 increase in fault frequency due to the relatively high levels of lightning activity that is experienced in this area. This data should be reviewed with PowerWater Corporation.

- Fault frequency on powerline section: fifteen phase to earth faults per annum
- Fault duration on powerline sections: 0.2 seconds

ARGON - SAFETY ASSESSMENT REPORT

Report Generated On : 26 August 2013

Report Generated By : Geoff Cope

from : Geoff Cope & Associates Pty Ltd

Design Location : Berry Springs MLV, AGP

INTRODUCTION

Individual Probability of Fatality

This report outlines the results of a risk-based safety criteria assessment study for the above location. The analysis is based on the fact that a fatality due to contact with an external voltage can only occur if both a person is present when a fault occurs and the touch (or step) voltage generated is sufficient to allow a large enough current to pass through the body for sufficient time to cause fibrillation of the heart muscle. The probability that an individual will be present and in contact with an item at the same time that the item is affected by a fault is defined as the Probability of Coincidence (Pcoinc). The probability that the heart will enter ventricular fibrillation due to contact with an external voltage is the Probability of Fibrillation (Pfibrillation). This situation can be described by the following simple equation:

$$P_{fatality} = P_{coinc} * P_{fibrillation}$$

The probability of coincidence has been calculated using contact and fault data as detailed in this report. The probability of fibrillation has been calculated using the impedance and applied voltage / clearing time information as detailed in this report.

The calculation of the probability of fatality allows the design to be classified according to accepted risk targets (1e-6 to 1e-4) as either negligible risk, intermediate risk or intolerable risk.

Design Compliance

Designs with low risk determination are accepted and the attached design curve(s) may be used at locations with similar contact, fault and series impedance characteristics. Designs which are determined as high risk are not acceptable and there is no valid design curve available until mitigation results in a compliant design. Designs placed in the intermediate risk range may be considered compliant as a result of applying the ALARA (As Low As Reasonably Achievable) principle. For designs of this type, documentation is supplied at the end of this report outlining the justification.

The following information outlines the design assumptions and classifies the compliance of the design.

COINCIDENCE PROBABILITY

Access / Fault Assumptions

Scenario Name User Defined Assumptions

Description Enter Contact data as required

					Individual	
Fault Frequency	15	*per year*	**Contact Frequency**	6	*per Year*
Fault Duration	0.2	*seconds*	**Contact Duration**	120	*seconds*

Coincidence Reduction

Concidence Reduction Method None

Concidence Reduction Factor 1

Individual Coincidence Probability = 3.43e-4

FIBRILLATION PROBABILITY

Assumptions

Current Path	Touch Voltage	
Footwear	Standard Footwear	
Wet / Dry ?	Dry	
Soil Resistivity	50	*Ω-m*
Applied Voltage	1180	*volts*
Fault Duration	0.2	*seconds*

Surface Layer

Type	Crushed Rock	
Resistivity	3000	*Ω-m*
Depth	0.1	*metres*
Flashover Voltage	Not Specified	*volts*

Fibrillation Probability = 0.0029

RISK DETERMINATION

Individual

Risk Zone : Negligible

Probability of Fatality = 9.975e-7

Argon Version : 3.4.0.0 Calculator Version : 2.0.0.0 Page 2 of 4

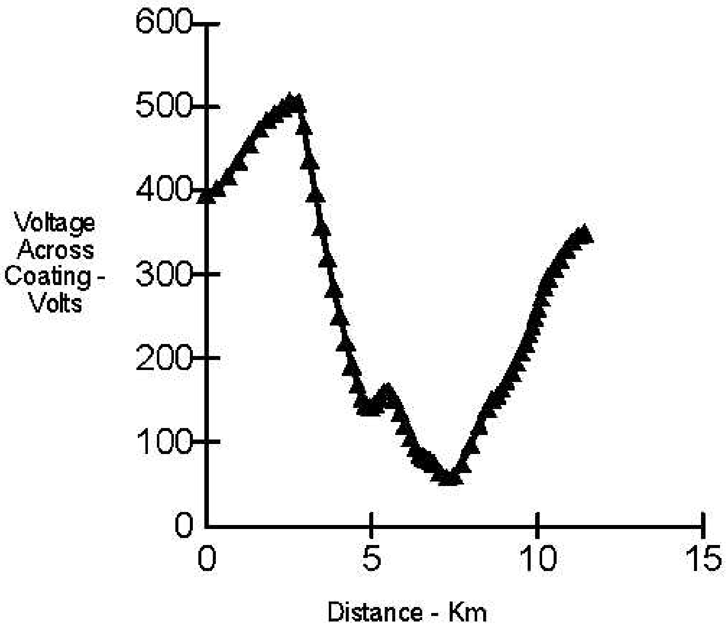
Addendum 3

Analysis and comment on proposed decommissioning of KP 1506 groundbed

APA Group are considering decommissioning the CP groundbed at KP 1506 as cathodic protection to the Channel Island pipeline is now being provided via an AGP connection at Darwin City Gate. Analysis of LFI effects under powerline fault conditions is shown on the following pages. This shows that the groundbed is having only a minor influence under fault conditions, with voltages due to faults at Manton or Hudson Creek changing maximum voltage levels by less than 5%. The measures that are recommended for fault current mitigation in this report are not affected by these changes.

Levels of steady state induction presently result in voltages that are approaching the recommended limits for AC corrosion as per CIGRE TB 290. As mentioned earlier in this report, evidence from electrical resistance probes and coating defect examinations indicate that AC corrosion is presently not a significant issue. Nevertheless it is highly desirable that any changes to the pipeline earthing systems should not increase the present AC level. Therefore it is recommended that AC data logging be conducted, together with directly observed voltage measurements while the groundbed connection is interrupted, to confirm that steady state AC levels would not be increased by the proposed decommissioning.

Fault Voltage
Graph and Data



Pipe #1		Pipe #1 (cont.)		Pipe #1 (cont.)	
Distance	Volts	Distance	Volts	Distance	Volts
0.00	396.3	5.53	161.1	9.85	237.8
0.32	402.5	5.69	151.3	9.94	248.4
0.64	417.3	5.85	135.4	10.03	259.9
0.97	434.9	6.02	119.9	10.12	272.1
1.29	455.2	6.18	105.0	10.22	284.6
1.61	473.6	6.34	92.9	10.32	296.6
1.84	484.5	6.45	86.2	10.51	307.7
2.07	491.6	6.55	82.5	10.69	318.6
2.31	499.4	6.66	79.9	10.88	329.7
2.54	508.2	6.77	78.6	11.06	339.3
2.77	505.5	6.88	74.2	11.26	346.3
2.95	477.6	7.08	64.6	11.45	349.4
3.13	437.1	7.28	58.1		
3.31	396.8	7.48	60.2		
3.49	357.1	7.73	74.3		
3.67	319.1	7.99	96.4		
3.85	284.1	8.25	120.2		
4.03	251.3	8.51	139.6		
4.21	220.0	8.65	150.1		
4.39	191.4	8.79	156.8		
4.57	168.3	8.93	164.2		
4.70	152.9	9.08	172.7		
4.83	144.1	9.22	182.9		
4.96	141.3	9.37	194.5		
5.09	145.0	9.52	206.8		
5.22	152.3	9.67	218.4		
5.38	159.4	9.76	228.1		

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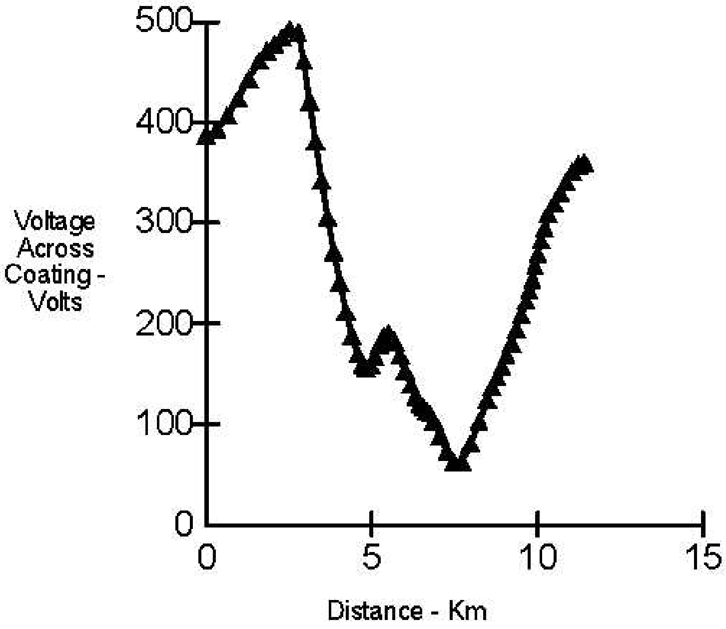
Pipeline voltage under phase to earth fault conditions, fault at Manton zone substation
Groundbed at KP 1506 connected (4 ohm earthing)

PRC INTERNATIONAL

Fault Voltage
Graph and Data



Pipe #1		Pipe #1 (cont.)		Pipe #1 (cont.)	
Distance	Volts	Distance	Volts	Distance	Volts
0.00	386.6	5.53	191.1	9.85	244.5
0.32	392.5	5.69	182.4	9.94	256.5
0.64	406.8	5.85	167.5	10.03	269.2
0.97	423.7	6.02	152.9	10.12	282.4
1.29	443.2	6.18	138.7	10.22	295.6
1.61	460.7	6.34	127.1	10.32	308.1
1.84	470.9	6.45	120.3	10.51	319.2
2.07	477.2	6.55	116.3	10.69	329.9
2.31	484.3	6.66	112.9	10.88	341.0
2.54	492.3	6.77	110.2	11.06	350.6
2.77	489.0	6.88	103.5	11.26	357.5
2.95	461.0	7.08	88.8	11.45	360.5
3.13	420.8	7.28	73.1		
3.31	381.0	7.48	61.8		
3.49	342.0	7.73	62.9		
3.67	305.2	7.99	80.4		
3.85	271.6	8.25	103.5		
4.03	240.6	8.51	123.9		
4.21	212.1	8.65	136.7		
4.39	187.3	8.79	146.5		
4.57	169.1	8.93	156.9		
4.70	159.2	9.08	168.4		
4.83	156.0	9.22	181.0		
4.96	158.7	9.37	194.6		
5.09	167.1	9.52	208.6		
5.22	178.0	9.67	221.8		
5.38	187.7	9.76	233.2		

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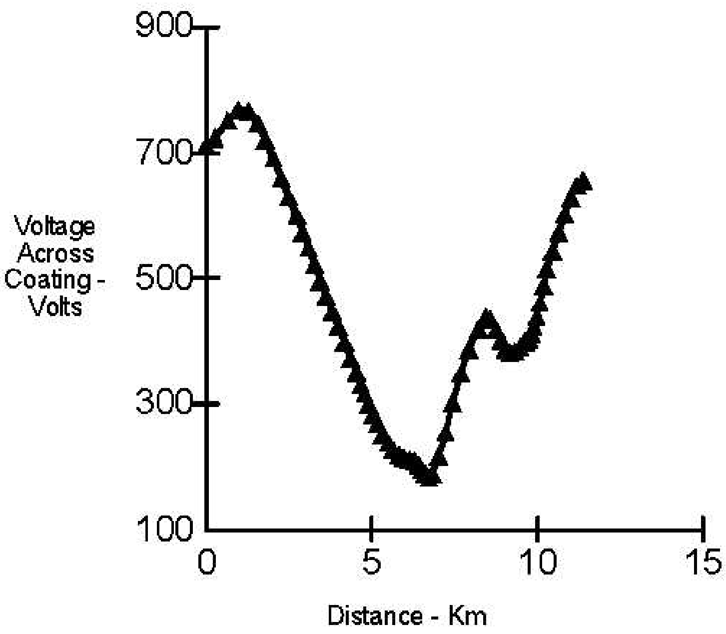
Pipeline voltage under phase to earth fault conditions, fault at Manton zone substation Groundbed at KP 1506 disconnected

Fault Voltage
Graph and Data



Pipe #1 Distance	Volts	Pipe #1 (cont.) Distance	Volts	Pipe #1 (cont.) Distance	Volts
0.00	709.9	5.49	237.2	9.81	410.5
0.25	722.9	5.65	226.6	9.90	422.6
0.66	750.4	5.81	219.2	9.99	439.5
0.97	768.2	5.98	213.9	10.08	461.1
1.27	765.4	6.14	211.2	10.18	486.1
1.57	745.3	6.30	208.5	10.28	513.7
1.80	718.4	6.41	202.6	10.47	542.5
2.03	690.2	6.51	195.1	10.65	571.7
2.27	660.5	6.62	188.6	10.84	600.9
2.50	629.6	6.73	183.1	11.02	626.8
2.73	599.6	6.84	188.7	11.22	646.5
2.91	572.9	7.04	216.0	11.41	655.3
3.09	547.8	7.24	255.3		
3.27	522.2	7.44	301.3		
3.45	496.2	7.69	349.9		
3.63	470.6	7.95	387.2		
3.81	445.8	8.21	418.0		
3.99	421.5	8.47	437.8		
4.17	396.9	8.61	433.6		
4.35	372.1	8.75	417.2		
4.53	349.3	8.89	400.7		
4.66	331.0	9.04	387.1		
4.79	314.8	9.18	380.6		
4.92	298.7	9.33	382.4		
5.05	282.8	9.48	390.3		
5.18	266.9	9.63	398.6		
5.34	251.2	9.72	403.7		

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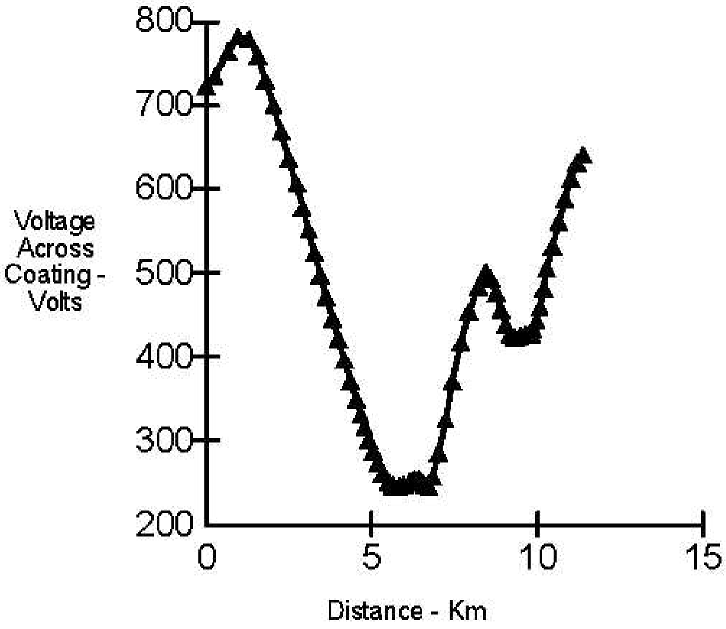
Pipeline voltage under phase to earth fault conditions, fault at Hudson Creek Groundbed at KP 1506 connected (4 ohm earthing)

PRC INTERNATIONAL

Fault Voltage
Graph and Data



Pipe #1		Pipe #1 (cont.)		Pipe #1 (cont.)	
Distance	Volts	Distance	Volts	Distance	Volts
0.00	722.2	5.49	251.2	9.81	427.2
0.25	735.5	5.65	246.5	9.90	433.0
0.66	763.6	5.81	245.7	9.99	444.0
0.97	782.0	5.98	247.4	10.08	460.2
1.27	779.2	6.14	251.5	10.18	480.9
1.57	758.3	6.30	255.0	10.28	505.3
1.80	730.2	6.41	253.8	10.47	532.3
2.03	700.7	6.51	250.4	10.65	560.2
2.27	669.7	6.62	248.1	10.84	588.1
2.50	637.4	6.73	246.9	11.02	612.8
2.73	606.0	6.84	256.4	11.22	632.0
2.91	578.2	7.04	286.1	11.41	640.5
3.09	551.9	7.24	325.9		
3.27	525.2	7.44	371.2		
3.45	498.1	7.69	418.3		
3.63	471.4	7.95	454.2		
3.81	446.0	8.21	483.2		
3.99	421.1	8.47	500.9		
4.17	396.2	8.61	494.6		
4.35	371.3	8.75	475.8		
4.53	348.7	8.89	456.2		
4.66	331.0	9.04	438.6		
4.79	315.8	9.18	427.2		
4.92	301.0	9.33	423.5		
5.05	286.7	9.48	425.5		
5.18	273.0	9.63	427.7		
5.34	260.6	9.72	426.7		

08/06/2013 - Page 2

Pipeline voltage under phase to earth fault conditions, fault at Hudson Creek Groundbed at KP 1506 disconnected